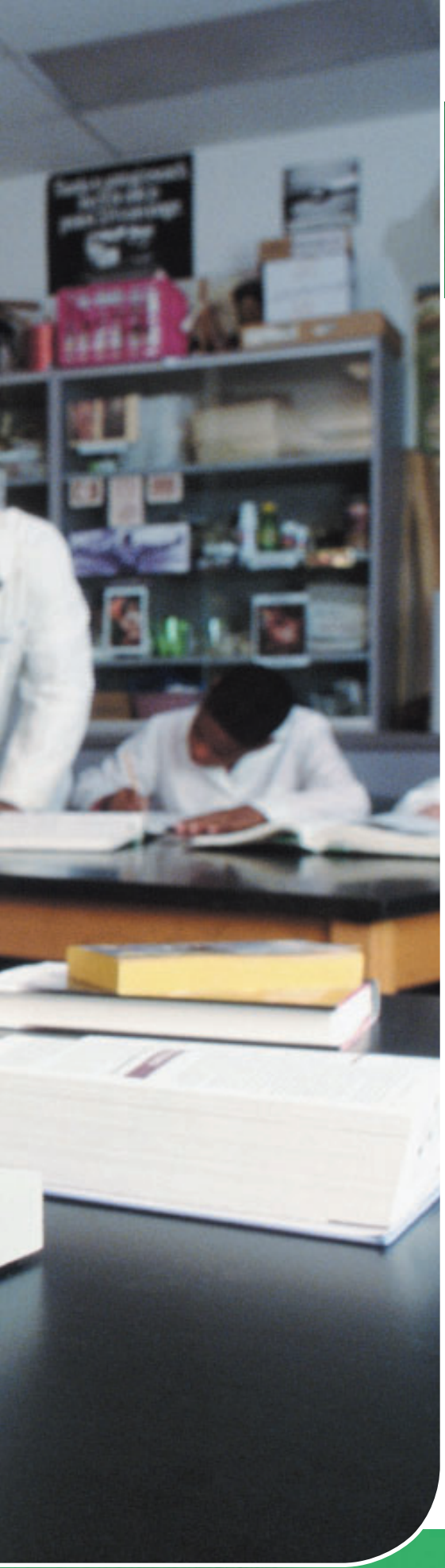

Appendices

A1 Scientific Inquiry

Planning an Investigation

In our attempts to further our understanding of the natural world, we encounter questions, mysteries, or events that are not readily explainable. To develop explanations, we investigate using scientific inquiry. The methods used in scientific inquiry depend, to a large degree, on the purpose of the inquiry.

Controlled Experiments

A controlled experiment is an example of scientific inquiry in which a **manipulated variable** is purposefully changed to determine its effect on a second **responding variable**. All other variables are controlled or kept constant. Controlled experiments are performed when the purpose of the inquiry is to create, test, or use a scientific concept.

The common components of controlled experiments are outlined below. *Note that there are normally many cycles through the steps during an actual experiment.*

Stating the Purpose

Every investigation in science has a purpose; for example,

- to develop a scientific concept (a theory, law, generalization, or definition);
- to test a scientific concept;
- to perform a chemical analysis;
- to determine a scientific constant.

Defining the Problem

The problem is the purpose of your experiment, rewritten in the form of a question. The problem forms the basis for your investigation: the investigation is designed to answer the question. Controlled experiments are about relationships, so the problem could be about the effects on variable A when variable B is changed.

Hypothesizing/Predicting

A **hypothesis** is a tentative explanation of the relationships being investigated by the experiment. Hypotheses propose an explanation for specific observations. For example, it is generally observed that plants die when kept in darkness. A hypothesis to explain this observation could be "Plants require solar energy to carry out photosynthesis." Hypotheses refer to general principles or observations, and are often based on current scientific knowledge, such as a theory or a law. Most importantly, to be useful in scientific inquiry, a hypothesis must be testable. In the example given here, the hypothesis could be tested by looking for a relationship between solar energy and the products of photosynthesis

The prediction states what you expect to observe in your particular experiment. It is more specific than the hypothesis: a prediction is a tentative answer to the problem you are investigating. Although it refers to your experiment, the prediction is always based upon the hypothesis. For example, a prediction might be "When plants are kept in darkness, they will not produce carbohydrates such as starch."

Designing the Investigation

The design of a controlled experiment identifies how you plan to change the manipulated variable, measure the responding variable, and control all the other variables in pursuit of an answer to the problem. It is a summary of your plan for the experiment.

Carrying Out the Procedure

When you carry out the procedure of an investigation, you are gathering evidence to support or refute your prediction and the hypothesis. Make sure you have read the procedure first (or, if you have designed it yourself, that you have received approval), and that you follow all safety procedures. As you work, you will need to gather and record data and observations (the evidence). Plan ahead and think about what data you will need and how best to record them. This helps to clarify your thinking and helps you to organize your evidence for easier analysis

Analyzing the Evidence

Analysis of the evidence involves looking for patterns and trends. This may involve creating graphs or making calculations. After analyzing the evidence, you may be able to answer the problem posed at the beginning of the investigation.

Evaluating the Evidence and the Hypothesis/Prediction

At this stage of the investigation, you evaluate the processes that you followed to plan and perform the investigation.

You will also evaluate the outcome of the investigation, which includes any prediction you made and the hypothesis or more established concept on which the prediction was based. You must identify and take into account any sources of error and uncertainty in your measurements.

Finally, compare the answer you predicted with the answer generated by analyzing the evidence. Does the evidence you gathered support or refute the hypothesis?

Reporting on the Investigation

In your report, describe your planning process and procedure clearly and in sufficient detail that the reader could repeat the experiment exactly as you performed it. You also must clearly communicate the evidence, analysis, and evaluation of your experiment accurately and honestly.

Observational Studies

Often the purpose of inquiry is simply to study a natural phenomenon, with the intention of gaining scientifically significant information. Observational studies involve observing a subject or phenomenon in an unobtrusive or unstructured manner, often with no specific hypothesis or prediction. A hypothesis to describe or explain the observations may, however, be generated after repeated observations, and modified as new information is collected over time.

The stages and processes of scientific inquiry through observational studies are summarized below. *Note that there are normally many cycles through the steps during the actual study.*

Stating the Purpose

Choose a topic that interests you. For example, a purpose of an observational study might be "To observe the organs of a fetal pig." Determine whether you are going to replicate or revise a previous study, or create a new one.

Stating the Problem

In an observational study, the problem is usually very general. For the purpose given above, the problem might be "What are the organ systems in a fetal pig and how are they organized?" Stating a problem can help you to focus the scope of your observations. You may or may not follow the problem with the creation of a hypothesis and/or a prediction.

Hypothesizing/Predicting

Observational studies usually do not involve a hypothesis or a prediction. A hypothesis can be formed after observations have been made and information gathered on a topic. A hypothesis may be created in the analysis.

Designing the Investigation

The design of an observational study describes how you will make observations relevant to the problem.

Gathering, Recording, and Organizing Observations

There are many ways to gather and record observations during an investigation. During your observational study, you should quantify your observations where possible. All observations should be objective and unambiguous. Consider ways to organize your information for easier analysis.

Analyzing the Observations

After thoroughly analyzing your observations, you may have sufficient and appropriate evidence to enable you to answer the problem posed at the beginning of the investigation. You may also have enough observations and information to form a hypothesis.

Evaluating the Evidence and the Hypothesis

At this stage of the investigation, you will evaluate the processes used to plan and perform the investigation. Evaluating the processes includes evaluating the materials, the design, the procedure, and your skills. The results of most such investigations will suggest further studies, perhaps correlational studies or controlled experiments to explore tentative hypotheses you may have developed.

Reporting on the Investigation

In your report, describe your design and procedure accurately, and report your observations accurately and honestly.

A2 Decision Making

Modern life is filled with environmental and social issues that have scientific and technological dimensions. An issue is defined as a problem that has at least two possible solutions rather than a single answer. There can be many positions on a single issue, generally determined by the values that an individual or a society holds. Which solution is "best" is a matter of opinion. Ideally, the solution that is implemented is the one that is most appropriate for society as a whole.

The common processes involved in the decision-making process are outlined below. *Note that you may go through several cycles before deciding you are ready to defend a decision.*

Defining the Issue

The first step in understanding an issue is to explain why it is an issue, describe the problems associated with the issue, and identify the individuals or groups, called stakeholders, involved in the issue. You could brainstorm the following questions to research the issue: Who? What? Where? When? Why? How? Develop background information on the issue by clarifying facts and concepts, and identifying relevant attributes, features, or characteristics of the problem.

Identifying Alternatives/Positions

Examine the issue and think of as many alternative solutions as you can. At this point it does not matter if the solutions seem unrealistic. To analyze the alternatives, you should examine the issue from a variety of perspectives. Stakeholders may bring different viewpoints to an issue and these may influence their position on the issue. Brainstorm or hypothesize how different stakeholders would feel about your alternatives. Perspectives that stakeholders may adopt while approaching an issue are listed in **Table 1**.

Researching the Issue

Formulate a research question that helps to limit, narrow, or define the issue. Then, develop a plan to identify and find reliable and relevant sources of information. Outline the stages of your information search: gathering, sorting, evaluating, selecting, and integrating relevant information. You may consider using a flow chart, concept map, or other graphic organizer to outline the stages of your information search. Gather information from many sources, including newspapers, magazines, scientific journals, the Internet, and the library.

Analyzing the Issue

In this stage, you will analyze the issue in an attempt to clarify where you stand. First, you should establish criteria for evaluating your information to determine its relevance and significance. You can then evaluate your sources, determine what assumptions may have been made, and assess whether you have enough information to make your decision.

There are five steps that must be completed to effectively analyze the issue:

1. Establish criteria for determining the relevance and significance of the data you have gathered.
2. Evaluate the sources of information.
3. Identify and determine what assumptions have been made. Challenge unsupported evidence.
4. Determine any causal, sequential, or structural relationships associated with the issue.
5. Evaluate the alternative solutions, possibly by conducting a risk-benefit analysis.

Table 1 Some Possible Perspectives on an Issue

cultural	focused on customs and practices of a particular group
environmental	focused on effects on natural processes and other living things
economic	focused on the production, distribution, and consumption of wealth
educational	focused on the effects on learning
emotional	focused on feelings and emotions
aesthetic	focused on what is artistic, tasteful, beautiful
moral/ethical	focused on what is good/bad, right/wrong
legal	focused on rights and responsibilities
spiritual	focused on the effects on personal beliefs
political	focused on the aims of an identifiable group or party
scientific	focused on logic or the results of relevant inquiry
social	focused on effects on human relationships, the community
technological	focused on the use of machines and processes

Defending the Decision

After analyzing your information, you can answer your research question and take an informed position on the issue. You should be able to defend your preferred solution in an appropriate format—debate, class discussion, speech, position paper, multimedia presentation, video, brochure, poster, or other creative formats.

Your position on the issue must be justified using the supporting information that you have discovered in your research and tested in your analysis. You should be able to defend your position to people with different perspectives. In preparing for your defence, ask yourself the following questions:

- Do I have supporting evidence from a variety of sources?
- Can I state my position clearly?
- Do I have solid arguments (with solid evidence) supporting my position?
- Have I considered arguments against my position, and identified their faults?
- Have I analyzed the strong and weak points of each perspective?

Evaluating the Process

The final phase of decision making includes evaluating the decision the group reached, the process used to reach the decision, and the part you played in decision making. After a decision has been reached, carefully examine the thinking that led to the decision. Some questions to guide your evaluation follow:

- What was my initial perspective on the issue? How has my perspective changed since I first began to explore the issue?
- How did we make our decision? What process did we use? What steps did we follow?
- In what ways does our decision resolve the issue?
- What are the likely short- and long-term effects of our decision?
- To what extent am I satisfied with our decision?
- What reasons would I give to explain our decision?
- If we had to make this decision again, what would I do differently?

Using a Risk–Benefit Analysis Model

Risk–benefit analysis is a tool used to organize and analyze information gathered in research. A thorough analysis of the risks and benefits associated with each alternative solution can help you decide on the best alternative.

- Research as many aspects of the proposal as possible. Look at it from different perspectives.
- Collect as much evidence as you can, including reasonable projections of likely outcomes if the proposal is adopted.
- Classify every individual potential result as being either a benefit or a risk.
- Quantify the size of the potential benefit or risk (perhaps as a dollar figure, or a number of lives affected, or in severity on a scale of 1 to 5).
- Estimate the probability (percentage) of that event occurring.
- By multiplying the size of a benefit (or risk) by the probability of its happening, you can assign a significance value for each potential result.
- Total the significance values of all the potential risks and all the potential benefits, and compare the sums to help you decide whether to accept the proposed action.

Note that although you should try to be objective in your assessment, your beliefs will have an effect on the outcome—two people, even if using the same information and the same tools, could come to a different conclusion about the balance of risk and benefit for any proposed solution to an issue.

A3 Lab Reports

When carrying out investigations, it is important that scientists keep records of their plans and results, and share their findings. In order to have their investigations repeated (replicated) and accepted by the scientific community, scientists generally share their work by publishing papers in which details of their design, materials, procedure, evidence, analysis, and evaluation are given.

Lab reports are prepared after an investigation is completed. To ensure that you can accurately describe the investigation, it is important to keep thorough and accurate records of your activities as you carry out the investigation.

Investigators use a similar format in their final reports or lab books, although the headings and order may vary. Your lab book or report should reflect the type of scientific inquiry that you used in the investigation and should be based on the following headings, as appropriate.

Title

At the beginning of your report, write the number and title of your investigation. In this course the title is usually given, but if you are designing your own investigation, create a title that suggests what the investigation is about. Include the date the investigation was conducted and the names of all lab partners (if you worked as a team).

Purpose

State the purpose of the investigation. Why are you doing this investigation?

Problem

This is the problem that you attempted to answer in the investigation. If it is appropriate to do so, state the problem in terms of manipulated and responding variables.

Hypothesis/Prediction

Based on your reasoning or on a concept that you have studied, make a prediction—a statement of what you expect to observe—before carrying out the investigation. You may also write a hypothesis, which is a tentative explanation of the relationships being investigated by the experiment. Hypotheses propose an explanation for specific observations. A hypothesis must always be testable. Whether or not you have a hypothesis or a prediction will depend on the nature of your investigation.

Design

This is a brief general overview (one to three sentences) of what was done. If your investigation involved manipulated, responding, and controlled variables, list them. Identify any control or control group that was used in the investigation.

Materials

This is a detailed list of all materials used, including sizes and quantities where appropriate. Be sure to include safety equipment such as eye protection, lab apron, latex gloves, and tongs, where needed. Draw a diagram to show any complicated setup of apparatus.

Procedure

In detailed, numbered steps, describe the procedure you followed to carry out your investigation. Include steps to clean up and dispose of waste.

Evidence

This includes all qualitative and quantitative observations you made. Be as precise as possible when describing quantitative observations. Include any unexpected observations and present your information in a form that is easily understood. If you have only a few observations, this could be a list; for controlled experiments and for many observations, a table will be more appropriate.

Analysis

Interpret your observations and present the evidence in the form of tables, graphs, or illustrations, each with a title. Include any calculations, the results of which can be shown in a table. Make statements about any patterns or trends you observed. Conclude the analysis with a statement based only on the evidence you have gathered, answering the problem that initiated the investigation.

Evaluation

The evaluation is your judgment about the quality of evidence obtained and about the validity of the prediction and hypothesis (if present). This section can be divided into two parts:

- Did your observations provide reliable and valid evidence to enable you to address the problem? Are you confident enough in the evidence to use it to evaluate any prediction and/or hypothesis you made?
- Was the prediction you made before the investigation supported or falsified by the evidence? Based on your evaluation of the evidence and prediction, is the hypothesis you used to make your prediction supported, or should it be rejected?

The leading questions that follow should help you through the process of evaluation.

Evaluation of the Experiment

1. Were you able to address the problem using the chosen experimental design? Are there any obvious flaws in the design? What alternative designs (better or worse) are available? To your knowledge, is this design the best available in terms of controls, efficiency, and cost? How great is your confidence in the chosen design?

   You may sum up your conclusions about the design in a statement like: "The experimental design [name or describe in a few words] is judged to be adequate/inadequate because…"
2. Were the steps that you used in the laboratory correctly sequenced, and adequate to gather sufficient evidence? What improvements could be made to the procedure? What steps, if not done correctly, would have significantly affected the results?

   Sum up your conclusions about the procedure in a statement like: "The procedure is judged to be adequate/inadequate because…"
3. Which specialized skills, if any, might have the greatest effect on the experimental results? Was the evidence from repeated trials reasonably similar? Can the measurements be made more precise?

   Sum up your conclusions: "The technological skills are judged to be adequate/inadequate because…"
4. You should now be ready to sum up your evaluation of the experiment. Do you have enough confidence in your experimental results to proceed with your evaluation of the hypothesis being tested? Based on uncertainties and errors you have identified in the course of your evaluation, what would be an acceptable percent difference for this experiment (1 %, 5 %, or 10 %)?

   State your confidence level in a summary statement: "Based upon my evaluation of the experiment, I am not certain/I am moderately certain/I am very certain of my experimental results. The major sources of uncertainty or error are…"

Evaluation of the Prediction

1. Calculate the percent difference for your experiment. Recall that the notation $|x|$ means the absolute value of x.

$$\%\ \text{difference} = \frac{|\text{experimental value}| - |\text{predicted value}|}{|\text{predicted value}|} \times 100\ \%$$

   How does the percent difference compare with your estimated total uncertainty (i.e. is the percent difference greater or smaller than the difference you've judged acceptable for this experiment)? Does the predicted answer clearly agree with the experimental answer in your analysis? Can the percent difference be accounted for by the sources of uncertainty listed earlier in the evaluation?

   Sum up your evaluation of the prediction: "The prediction is judged to be verified/inconclusive/falsified because…"
2. If the prediction was verified, the hypothesis behind it is supported by the experiment. If the results of the experiment were inconclusive or the prediction was falsified, then doubt is cast upon the hypothesis. How confident do you feel about any judgment you can make based on the experiment? Is there a need for a new or revised hypothesis, or to restrict, reverse, or replace the hypothesis being tested?

   Sum up your evaluation: "[The hypothesis] being tested is accepted/refuted because…"

Synthesis

When scientists publish their research, they often relate their observations to other research and to problems outside the laboratory. They may also describe additional research they plan to do, based on the results of their current experiments. In some Investigations in *Nelson Biology Alberta 20-30*, you will be guided in making these connections by a series of questions.

A4 Use of the Microscope

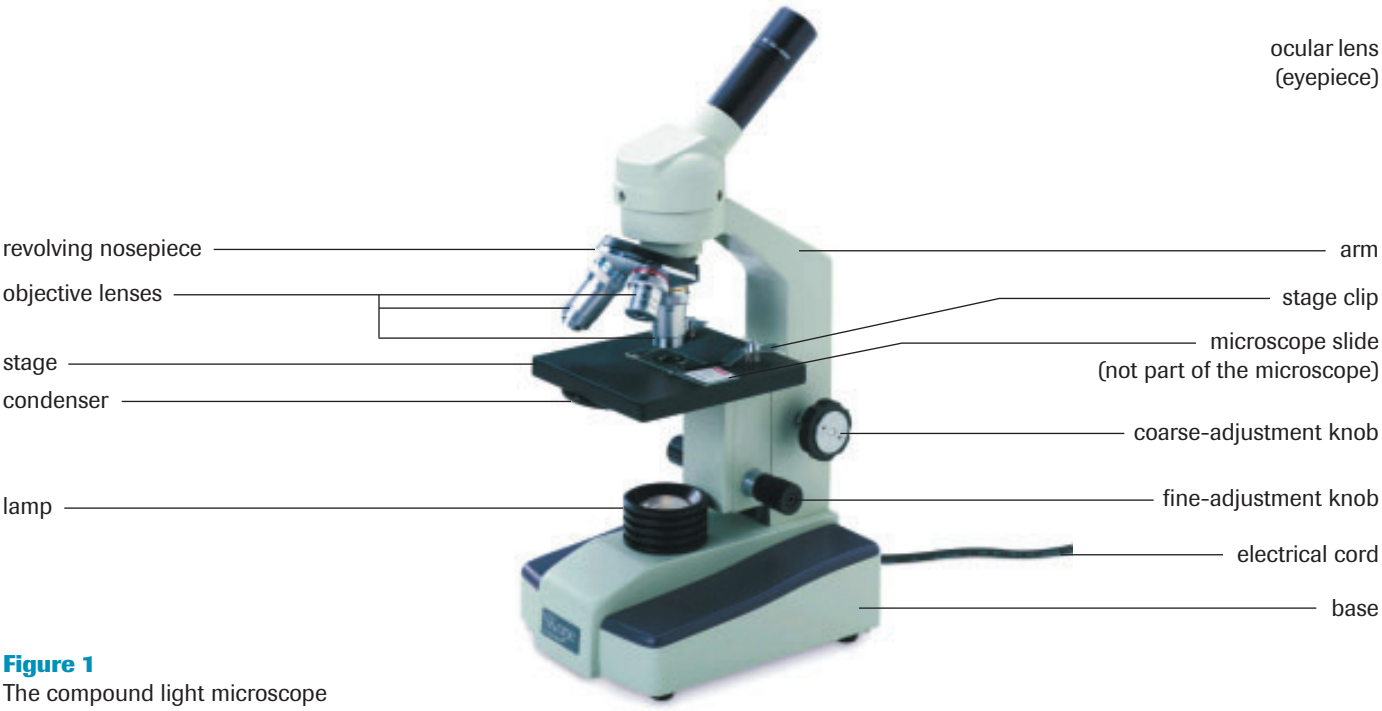

Figure 1
The compound light microscope

The microscope (**Figure 1**) is a useful tool in making observations and collecting data during scientific investigations in biology.

The eyepiece lens usually magnifies 10×. This information is printed on the side of the eyepiece.The microscopes that you will likely use have three objective lenses: low (magnifies 4×), medium (magnifies 10×), and high (magnifies 40×). To determine the total magnification, multiply the magnification of the eyepiece lens by the magnification of the objective lens. For example, the magnification obtained using the medium-power objective lens is 10× multiplied by 10×, or 100×.In other words, a specimen viewed under medium power will appear 100× larger than it actually is.

Use of the Compound Light Microscope

1. Obtain a microscope from the storage area. Grasp the arm with one hand and use the other to support the base of the microscope.
2. If the microscope has a built-in light supply, plug it in. Place the cord so that it will not be hooked accidentally.
3. Rotate the revolving nosepiece until the shortest (low-power) objective lens clicks into place.
4. Place a slide on the stage and centre it. Hold the slide in place with the stage clips.
5. Turn the coarse-adjustment knob away from you to lower the lens down as far as possible. Watch from the side to ensure that the lens does not contact the slide.
6. Keeping both eyes open, look through the eyepiece and turn the coarse-adjustment knob toward you until the specimen comes into view. Use the fine-adjustment knob to focus the image.
7. Adjust the condenser to control the amount of light and fix the contrast. If the microscope has a mirror in the base, adjust it to receive the appropriate amount of light.
8. With the image in focus and centred in the field of view, rotate the nosepiece until the next longer objective lens clicks into place.
9. Use the fine-adjustment knob to refocus the image, if necessary.
10. Readjust the condenser or the mirror to regulate the amount of light. The higher the lens power, the more light that is necessary.
11. Repeat the previous three steps with the high-power lens.

12. When you have finished viewing a specimen, always rotate the nosepiece so that the shortest (low-power) lens is centred before making any adjustments with the focusing knobs.
13. Remove and clean the slide and cover slip and return them to their appropriate location.
14. Return the microscope to the storage area.

Determining Field of View

It is often necessary to measure the size of objects viewed through the microscope. The field of view is the circle of light seen while looking through the eyepiece. Once the size of the field of view is determined, it is possible to estimate the size of a specimen by comparing it with the size of the field of view.

1. With the low-power objective lens in place, lay a microscope slide on the stage and place a transparent millimetre ruler on the slide.
2. Viewing the microscope stage from the side, position the millimetre marks on the ruler immediately below the objective lens.
3. Looking through the eyepiece, focus the marks on the ruler using the coarse- and fine-adjustment knobs.
4. Move the ruler so that one of the millimetre marks is at the edge of the field of view.
5. Use the following equations to calculate the diameter of the medium- and high-power fields of view. (*Note*: Magnification is shortened to mag. in the equations.)

   For medium power:

   $$\text{diameter} = \text{total mag.}_{\text{low power}} \times \frac{\text{diameter}_{\text{low power}}}{\text{total mag.}_{\text{medium power}}}$$

   For high power:

   $$\text{diameter} = \text{total mag.}_{\text{low power}} \times \frac{\text{diameter}_{\text{low power}}}{\text{total mag.}_{\text{high power}}}$$

6. Using a table similar to **Table 1**, determine the magnification of each of the lenses on your microscope, and record the diameter of the field of view.

Table 1 Characteristics of Microscope Lenses

Lens	Magnification	Eyepiece magnification	Total magnification	Diameter (mm)
low		10×		
medium		10×		
high		10×		

Estimating Size

- **Figure 2** shows the edge of a ruler under low power with the markings 1 mm apart. The diameter of the field of view is estimated to be 1.3 mm.

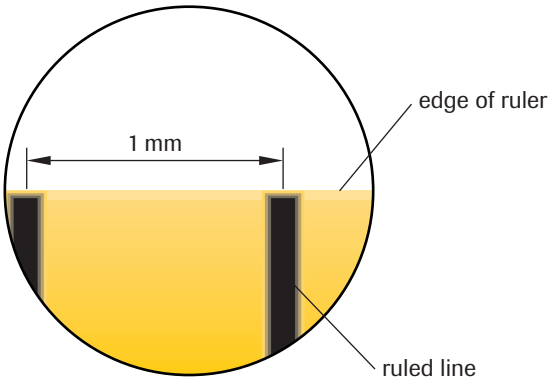

Figure 2
Markings of a ruler under low power

- Estimate the length and width of the specimen by comparing it to the diameter of the field of view.
- **Figure 3** shows a skin cell viewed under high power. One might estimate it to be 0.2 mm wide.

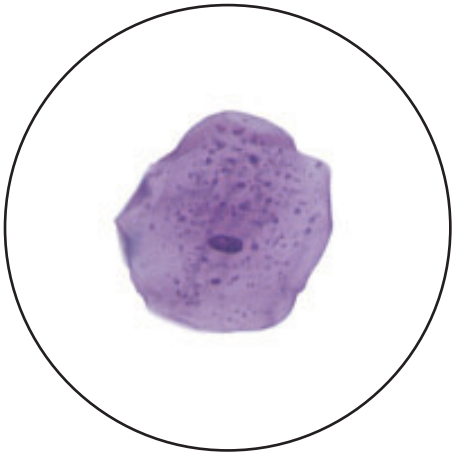

Figure 3
Skin cell viewed under high power

Preparing a Wet-Mount Slide

Specimens of all types can be mounted in a fluid medium before they are examined. Water is the most convenient, but 30 % glycerol can also be used. Glycerol helps make the material more transparent, and it does not dry out as fast as water does. A cover slip is used so that there are no reflecting surfaces.

1. Clean a slide and cover slip, holding them by the edges so that you do not leave fingerprints on them. Lay them on a clean, dry surface.

2. Place a drop of water or glycerol in the centre of the slide.
3. Transfer the specimen into the water or glycerol.
4. Hold the edges of the cover slip between thumb and forefinger. Place the cover slip in an almost vertical position on the slide so that the cover slip just touches the edge of the drop of water or glycerol (**Figure 4**).

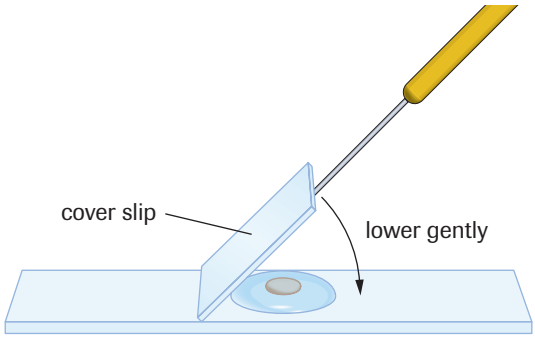

Figure 4
Preparing a wet mount

5. The water or glycerol will spread along the edge of the cover slip. Supporting the cover slip with the point of a needle, gently lower the cover slip onto the slide.
6. Use blotting paper to dry off any excess water or glycerol around the cover slip. Dry any water or glycerol that accidentally drops onto the stage of the microscope or onto the objective lenses.

Biological Drawings

Biological drawings are an essential part of recording your observations, both microscopic and macroscopic. These drawings are used to communicate, so it is very important that they are as accurate as possible, clear, well-labelled, and easy to understand. You will be required to make drawings of external features of whole specimens, parts of specimens, dissections, and prepared slides.

Preparation

- Use plain, white paper and a sharp, hard pencil (2H or 4H). Sharpen your pencil often to ensure clear, fine lines.
- Plan your drawing to fit on the page. Ensure that it is large enough to show the details.
- Leave space for labelling to the right of the drawing.

Drawing Tips

- Draw only what you see. Do not copy diagrams from books or draw what you think you should see.
- Use firm, clear lines. When recording microscope observations, use only the outline of structures for low-power observations; show details in high-power observations (**Figure 5**).

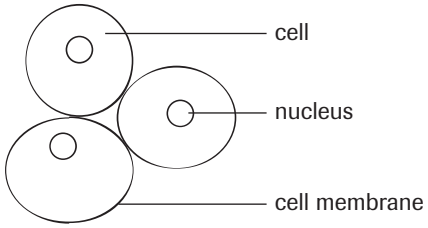

Figure 5
Clear, solid lines showing outlines of cells

- If important details are too small to be shown clearly, they should be shown in an enlarged drawing on the side.
- Don't use colouring or shading. To show darker areas, stippling (dots) may be used. Draw double lines to indicate thick structures (**Figure 6**).

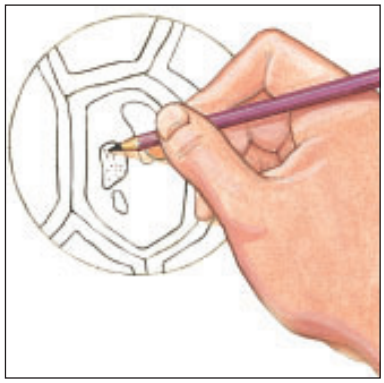

Figure 6
Use stippling to show darker areas and double lines to show thick structures.

- If a specimen shows repetitive structures, it is sufficient to draw only a representative section in detail (**Figure 7**).
- Don't draw on both sides of the paper.

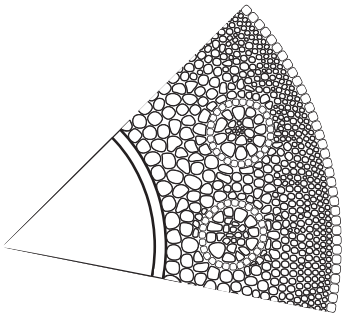

Figure 7
A representative drawing of a stem cross section.

Labelling

- All important structures should be labelled clearly. Always use the singular form for the labels (e.g., chloroplast, not chloroplasts).
- Connect labels to the appropriate parts using only horizontal lines if possible (**Figure 8**).

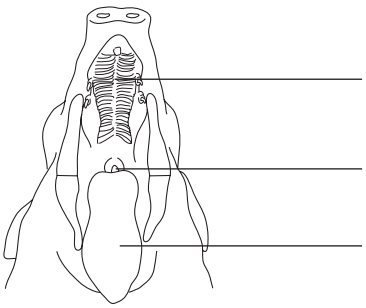

Figure 8
Connect your labels with horizontal lines.

- Don't label too close to the drawing, and never write on the drawing itself. It is preferable to list your labels in an even column down the right side (**Figure 9**).

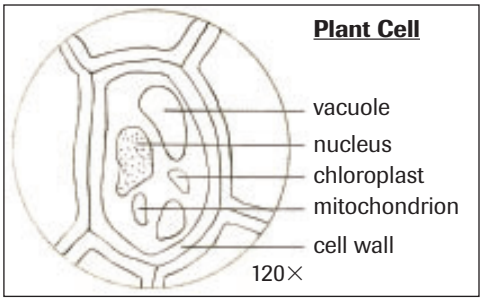

Figure 9
Neat labelling makes your drawing clear.

- For drawings of microscope observations, indicate the magnification.
- Title the drawing. Use the name of the specimen and any other information that will help identify the drawing. Underline the title.

A5 Preparing for the Biology 30 Diploma Exam

One goal of your studies is to prepare for the Biology 30 Diploma Exam. You have been provided opportunities to practice answering Diploma Exam-style questions in *Nelson Biology Alberta 20-30*. Part 1 of the Chapter and Unit Reviews contain multiple choice and numerical response questions. The numerical response questions are marked with this icon NR. Part 2 of the Chapter and Unit Reviews contain written-response questions, which are marked by this icon DE. The Case Studies also provide practice in answering closed-response written questions based on a scenario, and the Explore an Issue features help you to develop skills for answering open-response written questions. The **Additional Diploma Exam-style Review Questions** on the Nelson Web site are longer scenario-based questions, sometimes using published articles. Here are some general tips that will help you to answer Diploma Exam-style questions and to perform your best on the Diploma Exam.

- **Involve yourself in class**: Attend class regularly. Be active in your learning by asking questions and completing assignments. If you work steadily, you will not need to try to learn everything just before the exam.
- **Keep up-to-date with Biology 30 material:** Schedule a regular review time every week. Use this time to organize your notes, review the material, and ask yourself questions about what you have learned. Use the Self Quizzes, Chapter Summaries, and other study aids.
- **Read and understand the scoring criteria**: The scoring criteria for the different types of questions found in the Biology 30 Diploma Exam are available on the Nelson Web site. Read these criteria carefully and make sure you

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- **Practice writing old exams**: Use the old exams to simulate the conditions of the exam, including the time constraints. This will also help you practice answering the types of questions on the exam. Afterward, compare your answers to the scoring criteria to see where you can improve.
- **Read the instructions**: Make sure you read all instructions and questions very carefully.

Types of Questions on the Diploma Exam

There are three types of questions on the Diploma Exam: Multiple Choice, Numerical Response, and Written Response. Multiple choice and numerical response questions are found in Part 1 of the Diploma Exam, and written-response questions are found in Part 2.

Multiple Choice Questions

Multiple choice questions are a large part of the Diploma Exam. Most of the multiple choice questions on the Diploma Exam are context-dependent. The remainders are not context-dependent and are called discrete questions.

Context-dependent multiple choice questions use information provided in addition to the actual question. **Figure 1** and questions 1-4 are an example of this style.

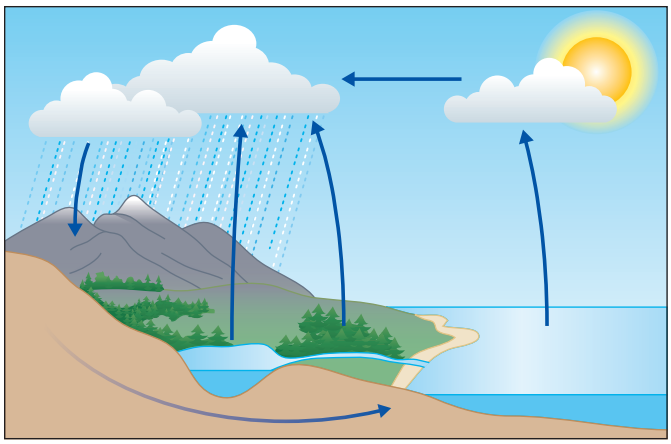

Figure 1

1. Identify three abiotic factors of the ecosystem shown in **Figure 1**.
   A. rain, sunlight, and soil quality
   B. water temperature, water lilies, and minnows
   C. poplars, grasses, and earthworms
   D. soil quality, bacteria, and earthworms

2. Explain how two members of the biotic community affect an abiotic factor.
   A. Pine trees and poplar trees affect the growth of grasses.
   B. Beavers and shrubs affect the number of poplar trees.
   C. Water temperature and pond oxygen levels affect the amount of plankton in the lake.
   D. Poplar trees and shrubs lose their leaves, which are decomposed and improve soil quality.

3. Identify the statement that lists two decomposers and correctly explains their role in the ecosystem.
   A. Clams and algae improve soil quality by returning organic nutrients to the soil.
   B. Bacteria and earthworms improve soil quality by returning organic nutrients to the soil.
   C. Pine trees and shrubs perform photosynthesis and add oxygen to the ecosystem.
   D. Algae and bacteria perform photosynthesis and add oxygen to the ecosystem.

4. What is the ultimate source of energy for the ecosystem shown in **Figure 1**?
   A. water
   B. sunlight
   C. producers
   D. consumers

Discrete multiple choice questions have no additional information or directions, such as in the following example.

5. The process of splitting water to release hydrogen ions, electrons, and oxygen occurs
   A. during the light-dependent reactions
   B. during the Calvin cycle
   C. during photorespiration
   D. during carbon fixation

Tips for Answering Multiple Choice Questions

- Try to answer the question before looking at the choices.
- Eliminate any choices that are incorrect by crossing them out.
- Stay alert for key words: *most, least, NOT one of the following*, etc. Negative terms ("Which of the following structures is *not* part of the respiratory system?) will be in italics.
- When writing the Diploma Exam, first mark the correct answer on the question sheet and then fill in the corresponding circle on the answer sheet at the end. Then, double-check to that you correctly marked your answer sheet. However, stay aware of time, so that you don't run out of time to transcribe your answers from the question sheet to the answer sheet.

Numerical Response Questions

There are three types of numerical response questions on the Diploma Exam. They are

- calculating of numerical values;
- selecting numerical responses from diagrams or lists; and
- determining the sequence of listed events.

Numerical response questions on the Diploma Exam are clearly indicated with the heading 'NUMERICAL RESPONSE'. The number of decimal places required is stated in the question. Examples of these types of questions are clearly marked with the icon 'NR' in this textbook.

Specific instructions for recording the answer to each type of numerical response are given in the instructions of the Diploma Exam, as well as with each question. Read the instructions CAREFULLY.

Tips for Answering Numerical Response Questions

For numerical calculations, use the provided data to determine an answer. The answer is a numerical response with a maximum of four digits (including the decimal point). The first digit of your answer goes in the left-hand box on the answer sheet. Depending on the number of digits in your answer, there may be unfilled boxes to the right. The decimal point, if there is one, occupies one of the boxes.

0	.	2	5

Numerical responses from diagrams or lists involves selecting numbers (usually representing a term or item from several provided) and writing them in the correct order.

Numerical responses that ask you to sequence numbered events or data require you to rearrange variables, events, or data into a specified order. Pay particular attention to the instructions, which might specify, for example, "in the order in which they occur during respiration."

Written-Response Questions

There are two written-response questions on the Biology 30 Diploma Exam. One written-response question is a closed-response question (which has only one correct response) and the other is an open-response question (to which there is more than one correct response). Learn to determine which type of question is being asked.

Closed-Response Questions

Closed-response questions have only one correct answer. In the Diploma Exam, these questions are presented as sections and subsections (question 1. a, b, c, etc.). They usually are based on current research or a scenario, and may provide data in graph or a table, as shown in the example on the next page.

Use the following information to answer question 34.

The data in **Table 2** compares Canadian population statistics for the periods 1861–1871 and 1991–1996. In 2004, the number of immigrants was about 236 000 while the number of emigrants was approximately 61 000.

Table 2 Canadian Population Statistics

	1861–1871	1991–1996
Population at beginning of period	3 229 000	27 852 000
Births	1 370 000	1 936 000
Deaths	760 000	1 024 000
Immigrants	260 000	1 137 000
Emigrants	410 000	229 000

Additional examples of closed-response questions can be found on the Nelson Web site.

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Open-Response Questions

Open-response questions have more than one possible answer. They usually include the phrase 'write a unified response…'. The question is asked as a series of bullets, and the answers are to be written in full sentences. Each bullet must be addressed and combined or 'unified' into the answer.

40. Darwin recognized that natural selection by the environment could produce change in a way similar to the artificial selection used by plant and animal breeders. Write a unified response that addresses the following aspects of these two processes.

- **Compare** the source of new variation in each process. **Illustrate** your answer with an example.
- **Describe** any role of selection *for* certain characteristics in each process. **Illustrate** your answer with an example.
- **Describe** any role of selection *against* certain characteristics in each process. **Illustrate** your answer with an example.
- **Compare** the length of time needed before noticeable differences can be seen. **Illustrate** your answer with an example.

Additional examples of closed-response questions can be found on the Nelson Web site.

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The questions are based on provided background information. Each bullet contains at least one directing word. Your final answer must address each bullet fully in order to get full credit. At least one of these bulleted questions usually requires you to make and defend a judgment or opinion. Two separate scoring scales are used. One is based on the scientific aspects of your answer and the other is based on addressing technological, societal, and/or environmental aspects of your answer.

Tips for Answering Written-Response Questions

- Carefully read the information box and make sure you fully understand the material *and* all of the question parts before beginning to answer.
- Identify each key piece of information and make notes about the meaning and implications of that information. If it helps, mark key words and phrases. Identify which unit of Biology 30 is being addressed, to help focus your attention to the correct material.
- Identify any irrelevant information.
- Identify the **directing words** in the question. These are highlighted in bold in the question. The directing words have specific meanings and are indicators of what the graders expect for an answer. Examples of directing words include **illustrate**, **analyze**, **explain**, and **predict**. A complete list of directing words and their meanings can be found online. The Glossary includes directing words used in this textbook. Make sure that you know what is expected for each directing word.

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- Read the question carefully and ask yourself what you are being asked to do. Write the question out in your own words if there are any doubts. Remember, if you don't understand the question, you will probably not be able to answer it correctly!
- Summarize your answers on scrap paper before writing them on the test answer page.
- Once you have answered the question, review your answer and make sure you have addressed all parts of the question.

A6 Graphic Organizers

Graphic organizers such as those outlined in this section can help you to solidify your understanding of a topic, and assist you in formulating a clear, concise answer.

PMI Chart

A PMI chart is used to examine both sides of an issue. Positive aspects of a topic or issue are recorded in the P (plus) column. Negative aspects are recorded in the M (minus) column. Interesting or controversial questions are recorded in the I (interesting) column (**Table 1**).

Table 1: A PMI Chart

P	M	I

Table 2: A KWL Chart

K	W	L

KWL Chart

A KWL chart can help you identify prior knowledge and experience, decide what new information you want to learn about, and reflect on your learning. Before you begin a new concept, lesson, or unit, list what you know about a topic in the K column and what you want to know in the W column. After studying the new topic, list what you learned in the L column (**Table 2**).

Venn Diagram

A Venn diagram is used to show similarities and differences in two or more concepts. Write all similarities between the concepts in the overlapping section of the circles and all unique traits of each concept in the nonoverlapping parts of the appropriate circles (**Figure 1**).

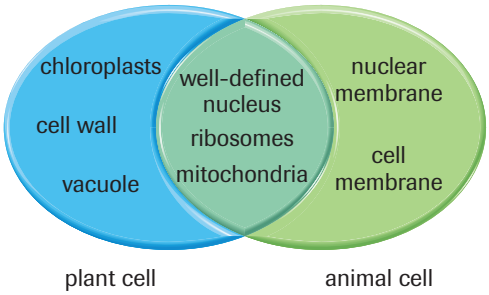

Figure 1
Venn diagram: plant and animal cells

Fishbone Diagram

A fishbone diagram is used to identify separate causes and effects. In the head of the fish, identify the effect, topic, or result. At the end of each major bone, identify the major subtopics or categories. On the minor bones that attach to each major bone, add details about the subtopics or possible causes of each effect or result (**Figure 2**).

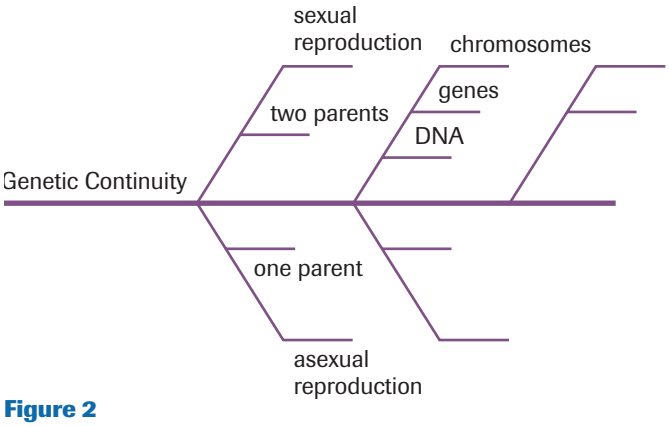

Figure 2
Fishbone diagram: genetic continuity

The Concept Map

Concept maps are used to show connections between ideas and concepts, using words or visuals. Put the central idea in the middle of a sheet of paper. Organize the ideas most closely related to each other around the centre. Draw arrows between the ideas that are related. On each arrow, write a short description of how the terms are related to each other (**Figure 3**).

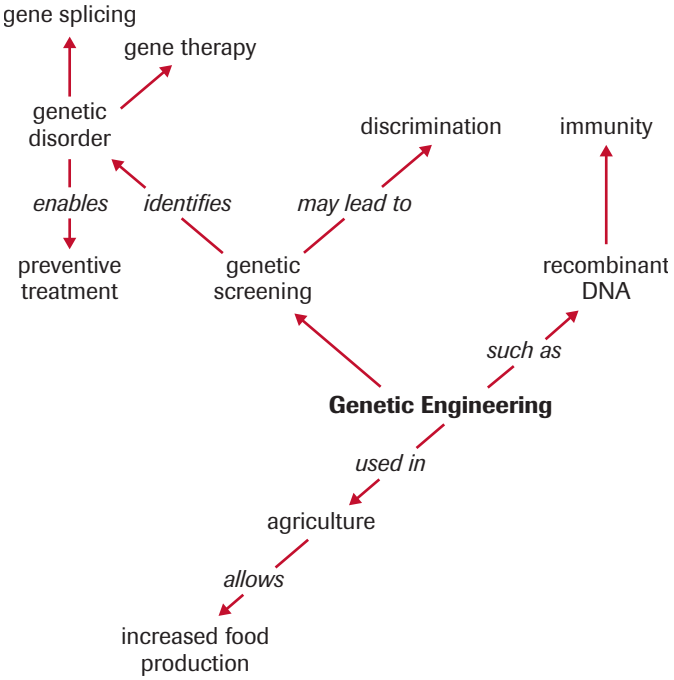

Figure 3
Concept map: genetic engineering

A7 Math Skills

Scientific Notation

It is difficult to work with very large or very small numbers when they are written in common decimal notation. Usually, it is possible to accommodate such numbers by changing the SI prefix so that the number falls between 0.1 and 1000. For example, 237 000 000 mm can be expressed as 237 km and 0.000 000 895 kg can be expressed as 0.895 mg. However, this prefix change is not always possible. An appropriate prefix may not exist or it may be essential to use a particular unit of measurement. In these cases, the best method of dealing with very large and very small numbers is to write them using scientific notation. Scientific notation expresses a number by writing it in the form $a \times 10^n$, where $1 < |a| < 10$ and the digits in the coefficient a are all significant. Recall that the notation $|x|$ means the absolute value of x. **Table 1** shows situations where scientific notation would be used.

Table 1 Examples of Scientific Notation

Expression	Common decimal notation	Scientific notation
124.5 million kilometres	124 500 000 km	1.245×10^8 km
154 thousand picometres	154 000 pm	1.54×10^{-5} pm
602 sextillion /mol	602 000 000 000 000 000 000 000 /mol	6.02×10^{23}/mol

To multiply numbers in scientific notation, multiply the coefficients and add the exponents; the answer is expressed in scientific notation. Note that when writing a number in scientific notation, the coefficient should be between 1 and 10 and should be rounded to the same certainty (number of significant digits) as the measurement with the least certainty (fewest number of significant digits). Look at the following examples:

$$(4.73 \times 10^5 \text{ m})(5.82 \times 10^7 \text{ m}) = 27.5 \times 10^{12} \text{ m}^2 = 2.75 \times 10^{13} \text{ m}^2$$

$$(3.9 \times 10^4 \text{ N})(5.3 \times 10^{-3} \text{ m}) = 21 \times 10^1 \text{ N•m} = 2.1 \times 10^2 \text{ N•m}$$

On many calculators, scientific notation is entered using a special key, labelled EXP or EE. This key includes "$\times 10$" from the scientific notation; you need to enter only the exponent. For example, to enter

7.5×10^4	press	7.5 EXP 4
3.6×10^{-3}	press	3.6 EXP +/− 3

Logarithms

In the exponential equation $y = a^n$, a is the base and n is the exponent. $y = a^n$ can be written as $\log_a y = n$ ($a > 0$ and $a \neq 1$) and is read as "the logarithm of y with base a is equal to n." For example, $10^2 = 100$ can be written as $\log_{10} 100 = 2$.

On many scientific calculators, the key "LOG" calculates the logarithm of a number with base 10. For example, to enter

$\log_{10} 2$	press	LOG 2

Logarithm of a product is one of the logarithm laws. The law is as follows:

$$\log_a(mn) = \log_a m + \log_a n$$

This law is useful when calculating the pH of solutions. The definition of pH is the negative logarithm of the hydronium ion concentration, $-\log_{10}[H_3O^+_{(aq)}]$, where the concentration is measured in moles per litre of solution (mol/L).

In pure water at 25 °C, the $H_3O^+_{(aq)}$ is 1.0×10^{-7} mol/L.

$$\begin{aligned} \text{pH} &= -\log_{10}[H_3O^+_{(aq)}] \\ &= -\log_{10}(1.0 \times 10^{-7}) \\ &= -((\log_{10} 1.0) + \log_{10}(10^{-7})) \\ &= -(0 + (-7)) \\ &= 7 \end{aligned}$$

Therefore, the pH of pure water is 7.

Uncertainty in Measurements

There are two types of quantities that are used in science: exact values and measurements. Exact values include defined quantities (1 m = 100 cm) and counted values (5 cars in a parking lot). Measurements, however, are not exact because there is some uncertainty or error associated with every measurement.

There are two types of measurement error. **Random error** results when an estimate is made to obtain the last significant figure for any measurement. The size of the random error is determined by the precision of the measuring instrument. For example, when measuring length, it is necessary to estimate between the marks on the measuring tape. If these marks are 1 cm apart, the random error will be greater and the precision will be less than if the marks are 1 mm apart.

Systematic error is associated with an inherent problem with the measuring system, such as the presence of an interfering substance, incorrect calibration, or room conditions. For example, if the balance is not zeroed at the beginning, all measurements will have a systematic error; if using a metre

stick that has been worn slightly, all measurements will contain an error.

The precision of measurements depends upon the gradations of the measuring device. **Precision** is the place value of the last measurable digit. For example, a measurement of 12.74 cm is more precise than a measurement of 127.4 cm, because the first value was measured to hundredths of a centimetre, whereas the latter was measured to tenths of a centimetre.

When adding or subtracting measurements of different precision, the answer is rounded to the same precision as the least precise measurement. For example, using a calculator, add

$$11.7 \text{ cm} + 3.29 \text{ cm} + 0.542 \text{ cm} = 15.532 \text{ cm}$$

The answer must be rounded to 15.5 cm, because the first measurement limits the precision to a tenth of a centimetre.

No matter how precise a measurement is, it still may not be accurate. **Accuracy** refers to how close a value is to its true value. The comparison of the two values can be expressed as a percentage difference. The percentage difference is calculated as:

$$\%\text{ difference} = \frac{|\text{experimental value} - \text{predicted value}|}{\text{predicted value}} \times 100\ \%$$

Figure 1 shows an analogy between precision and accuracy, and the positions of darts thrown at a dartboard.

How certain you are about a measurement depends on two factors: the precision of the instrument used and the size of the measured quantity. More precise instruments give more certain values. For example, a mass measurement of 13 g is less precise than a measurement of 12.76 g; you are more certain about the second measurement than the first. Certainty also depends on the measurement. For example, consider the measurements 0.4 cm and 15.9 cm; both have the same precision. However, if the measuring instrument is precise to ± 0.1 cm, the first measurement is 0.4 ± 0.1 cm (0.3 cm or 0.5 cm) or an error of 25 %, whereas the second measurement could be 15.9 ± 0.1 cm (15.8 cm or 16.0 cm) for an error of 0.6 %. For both factors—the precision of the instrument used and the value of the measured quantity—the more digits there are in a measurement, the more certain you are about the measurement.

Significant Digits

The certainty of any measurement is communicated by the number of significant digits in the measurement. In a measured or calculated value, significant digits are the digits that are certain plus one estimated (uncertain) digit. Significant digits include all digits correctly reported from a measurement.

Follow these rules to decide if a digit is significant:

1. For any non-logarithmic value, zeros to the left of the first non-zero digit (leading zeros) are not significant.
2. Zeros to the right of the last non-zero digit (trailing zeros) of any value are significant.
3. All other digits are significant.
4. When a measurement is written in scientific notation, all digits in the coefficient are significant.
5. For all logarithmic values such as pH, any digit to the left of the decimal is not significant.
6. Counted and defined values have infinite significant digits.

Table 2 shows some examples of significant digits.

Table 2 Certainty in Significant Digits

Measurement	Number of significant digits
32.07 m	4
0.0041 g	2
5×10^5 kg	1
6400 s	4
pH 6.47	2

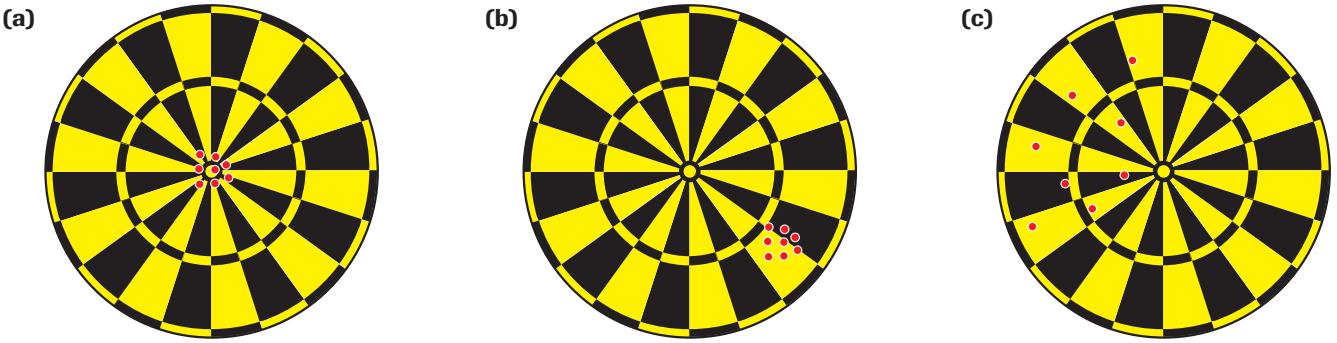

Figure 1
The positions of the darts in each of these figures are analogous to measured or calculated results in a laboratory setting. The results in **(a)** are precise and accurate, in **(b)** they are precise but not accurate, and in **(c)** they are neither precise nor accurate.

Rounding Off

An answer obtained by multiplying and/or dividing measurements is rounded to the same number of significant digits as the measurement with the fewest number of significant digits. For example, we could use a calculator to solve the following equation:

$$77.8 \text{ km/h} \times 0.8967 \text{ h} = 69.76326 \text{ km}$$

However, the certainty of the answer is limited to three significant digits, so the answer is rounded up to 69.8 km.

The following rules should be used when rounding answers to calculations.

1. When the first digit discarded is less than five, the last digit retained should not be changed.

   3.141 326 rounded to 4 digits is 3.141

2. When the first digit discarded is greater than five, or if it is a five followed by at least one digit other than zero, the last digit retained is increased by 1 unit.

   2.213 724 rounded to 4 digits is 2.214

   4.168 501 rounded to 4 digits is 4.169

3. When the first digit discarded is five followed by only zeros, the last digit retained is increased by 1 if it is odd, but not changed if it is even.

   2.35 rounded to 2 digits is 2.4

   2.45 rounded to 2 digits is 2.4

   −6.35 rounded to 2 digits is −6.4

Measuring and Estimating

Many people believe that all measurements are reliable (consistent over many trials), precise (to as many decimal places as possible), and accurate (representing the actual value). But there are many things that can go wrong when measuring.

- There may be limitations that make the instrument or its use unreliable (inconsistent).
- The investigator may make a mistake or fail to follow the correct techniques when reading the measurement to the available precision (number of decimal places).
- The instrument may be faulty or inaccurate; a similar instrument may give different readings.

For example, when measuring the temperature of a liquid, it is important to keep the thermometer at the proper depth and the bulb of the thermometer away from the bottom and sides of the container. If you sit a thermometer with its bulb at the bottom of a liquid-filled container, you will be measuring the temperature of the bottom of the container and not the temperature of the liquid. There are similar concerns with other measurements.

To be sure that you have measured correctly, you should repeat your measurements at least three times. If your measurements appear to be reliable, calculate the mean and use that value. To be more certain about the accuracy, repeat the measurements with a different instrument.

Every measurement is a best estimate of the actual value. The measuring instrument and the skill of the investigator determine the certainty and the precision of the measurement. The usual rule is to make a measurement that estimates between the smallest divisions on the scale of the instrument.

Probability

In scientific investigations, probability is a measure of the likelihood of a specific event occurring and is usually expressed as a number between 0 and 1. A probability of 0 means the event will not occur; a probability of 1 means the event will definitely occur. Probabilities may also be expressed as fractions or as percents.

There are two types of probability: theoretical probability and experimental probability. Theoretical probability is the likelihood of an event occurring based on the information known about certain conditions. This is an expectation.

$$\text{theoretical probability} = \frac{\text{number of desired outcomes}}{\text{total number of possible outcomes}}$$

Example

Black fur colour is a dominant trait in guinea pigs, while white fur colour is a recessive trait. What is the theoretical probability of a pair of heterozygous black guinea pigs (*Bb*) producing offspring with white fur (*bb*)?

Using a Punnett square (**Figure 2**), we show that if four offspring were produced, it is expected that three would have black fur and one would have white fur.

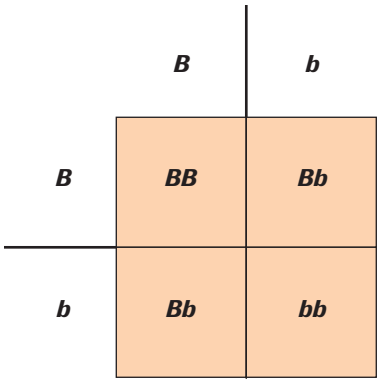

Figure 2
Punnett square showing a *Bb* × *Bb* cross

$$\text{theoretical probability} = \frac{\text{number of desired outcomes}}{\text{total number of possible outcomes}}$$

$$= \frac{\text{number of offspring with white fur}}{\text{total number of possible offspring}}$$

$$= \frac{1}{4}$$

$$= 0.25$$

$$= 25\ \%$$

The theoretical probability of producing white offspring is 1/4 or 25 %. So, if a litter had eight offspring, you could expect two to have white fur.

Experimental probability is based on the recorded outcomes or events of an investigation. The more often an experiment is repeated or the more observations made, the closer the experimental probability will be to the theoretical probability.

$$\text{experimental probability} = \frac{\text{number of desired outcomes observed}}{\text{total number of observations}}$$

Example

Black fur colour is a dominant trait in guinea pigs, while white fur colour is a recessive trait. Two heterozygous black guinea pigs (*Bb*) were crossed. The litter contained six offspring with black fur and one with white fur. What is the experimental probability of producing offspring with white fur?

$$\text{experimental probability} = \frac{\text{number of desired outcomes observed}}{\text{total number of observations}}$$

$$= \frac{\text{number of offspring with white fur}}{\text{total number of possible offspring}}$$

$$= \frac{1}{7}$$

$$\doteq 0.14$$

$$= 14\ \%$$

The experimental probability of having offspring with white fur is 14%. If you performed the same analysis on a large number of litters, you would expect the experimental probability to be the same as (or very close to) the theoretical probability.

Graphs

There are many types of graphs that you can use to organize your data. You need to identify which type of graph is best for your data before you begin graphing. Three of the most useful kinds are bar graphs, circle (pie) graphs, and point-and-line graphs.

Bar Graphs

When at least one of the variables is qualitative, use a bar graph to organize your data (**Figure 3**). For example, a bar graph would be a good way to present the data collected from a study of the number of plants (quantitative) and the type of plants found (qualitative) in a local nursery. In this graph, each bar stands for a different category, in this case a type of plant.

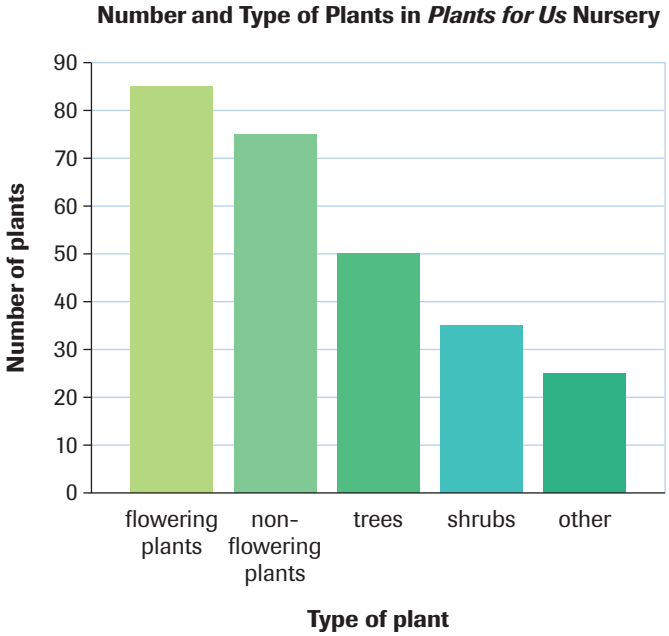

Figure 3
Bar graph

Circle Graphs

Circle graphs and bar graphs are used for similar types of data. A circle graph is used if the quantitative variable can be changed to a percentage of a total quantity (**Figure 4**). For example, if you surveyed a local nursery to determine the types of plants found and the number of each, you could make a circle graph. Each piece in the graph stands for a different category (e.g., the type of plant). The size of each piece is determined by the percentage of the total that belongs in each category (e.g., the percentage of plants of a particular type).

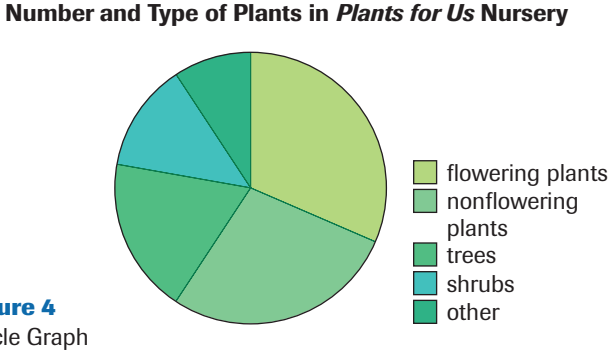

Figure 4
Circle Graph

Point-and-Line Graphs

When both variables are quantitative, use a point-and-line graph. For example, we can use the following guidelines and the data in **Table 3** to construct the point-and-line graph shown in **Figure 5**.

Table 3 Number of Brine Shrimp Eggs Hatched in Salt Solutions of Various Concentrations

Day	2 % salt	4 % salt	6 % salt	8 % salt
1	0	0	0	1
2	0	11	2	3
3	0	14	8	5
4	2	20	17	8
5	5	37	25	15
6	6	51	37	31

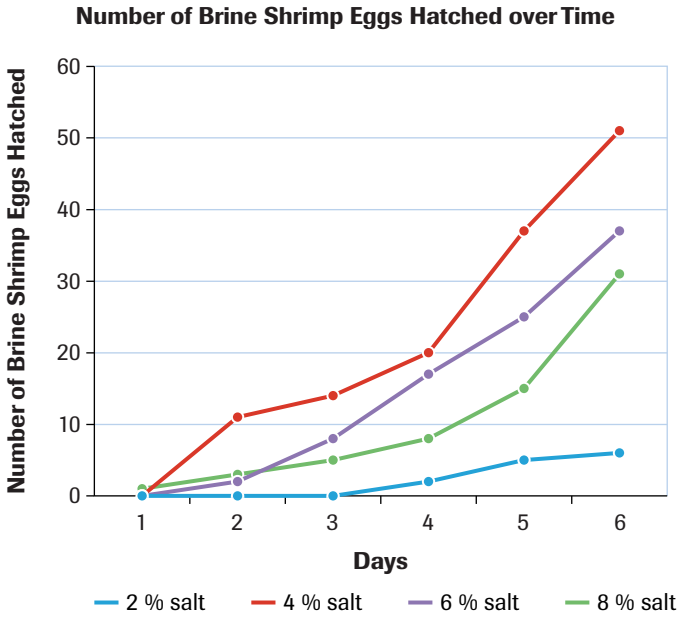

Figure 5
Point-and-line graph

1. Use graph paper and construct your graph on a grid. The horizontal edge on the bottom of this grid is the *x*-axis and the vertical edge on the left is the *y*-axis. Do not be too thrifty with graph paper—a larger graph is easier to interpret.
2. Decide which variable goes on which axis and label each axis, including the units of measurement. The manipulated variable is generally plotted along the *x*-axis and the responding variable along the *y*-axis. The exception to this is when you plot a variable against time: regardless of which is the manipulated or responding variable, always plot time on the *x*-axis. This convention ensures that the slope of the graph always represents a rate.
3. Title your graph. The title should be a concise description of the data contained in the graph.
4. Determine the range of values for each variable. The range is the difference between the largest and smallest values. Graphs often include a little extra length on each axis, to make them appear less cramped.
5. Choose a scale for each axis. This will depend on how much space you have and the range of values for each axis. Each line on the grid usually increases steadily in value by a convenient number, such as 1, 2, 5, 10, or 50.
6. Plot the points. Start with the first pair of values, which may or may not be at the origin of the graph.
7. After all the points are plotted, draw a line through the points to show the relationship between the variables, if possible. Not all points may lie exactly on a line; small errors in each measurement may have occurred and moved the points away from the perfect line. Draw a line that comes closest to most of the points. This is called the line of best fit—a smooth line that passes through or between the points so that there are about the same number of points on each side of the line. The line of best fit may be straight or curved.
8. If you are plotting more than one set of data on one graph, use different colours or symbols to indicate the different sets, and include a legend (**Figure 5**).

Spreadsheets

A spreadsheet is a useful tool for creating different graph types such as column, bar, line, and circle to display data.

The following steps show how the data for the plants in a local nursery can be used to create a column (or bar) graph.

Step 1

Enter the data in the spreadsheet.

Step 2

Select the graph type that will display the data in the most appropriate form.

Step 3

Select the data from the spreadsheet that will be plotted on the graph.

Step 4

Enter the remaining graph information, such as the graph title and axes titles.

Step 5

Indicate where the graph is to be located in the spreadsheet. It can be included on the same sheet as the data or on a new sheet.

B1 Safety Conventions and Symbols

Although every effort is undertaken to make the science experience a safe one, there are inherent risks associated with some scientific investigations. These risks are generally associated with the materials and equipment used, and the disregard of safety instructions that accompany investigations. However, there may also be risks associated with the location of the investigation, whether in the science laboratory, at home, or outdoors. Most of these risks pose no more danger than one would normally experience in everyday life. With an awareness of the possible hazards, knowledge of the rules, appropriate behaviour, and a little common sense, these risks can be practically eliminated.

Remember, you share the responsibility not only for your own safety, but also for the safety of those around you. Always alert the teacher in case of an accident.

In this text, chemicals, equipment, and procedures that are hazardous are highlighted in red and are preceded by the appropriate Workplace Hazardous Materials Information System (WHMIS) symbol or by  .

WHMIS Symbols and HHPS

The Workplace Hazardous Materials Information System (WHMIS) provides workers and students with complete and accurate information regarding hazardous products. All chemical products supplied to schools, businesses, and industries must contain standardized labels and be accompanied by Material Safety Data sheets (MSDS) providing detailed information about the product. Clear and standardized labelling is an important component of WHMIS (**Table 1**). These labels must be present on the product's original container or be added to other containers if the product is transferred.

The Canadian Hazardous Products Act requires manufacturers of consumer products containing chemicals to include a symbol specifying both the nature of the primary hazard and the degree of this hazard. In addition, any secondary hazards, first aid treatment, storage, and disposal must be noted. Household Hazardous Product Symbols (HHPS) are used to show the hazard and the degree of the hazard by the type of border surrounding the illustration (**Figure 1**).

	Corrosive
	This material can burn your skin and eyes. If you swallow it, it will damage your throat and stomach.
	Flammable
	This product or the gas (or vapour) from it can catch fire quickly. Keep this product away from heat, flames, and sparks.
	Explosive
	Container will explode if it is heated or if a hole is punched in it. Metal or plastic can fly out and hurt your eyes and other parts of your body.
	Poisonous
	If you swallow or lick this product, you could become very sick or die. Some products with this symbol on the label can hurt you even if you breathe (or inhale) them.

Figure 1
Hazardous household product symbols

Table 1 The Workplace Hazardous Materials Information System (WHMIS)

Class and type of compounds	WHMIS symbol	Risks	Precautions
Class A: *Compressed Gas* Material that is normally gaseous and kept in a pressurized container		• could explode due to pressure • could explode if heated or dropped • possible hazard from both the force of explosion and the release of contents	• ensure container is always secured • store in designated areas • do not drop or allow to fall
Class B: *Flammable and Combustible Materials* Materials that will continue to burn after being exposed to a flame or other ignition source		• may ignite spontaneously • may release flammable products if allowed to degrade or when exposed to water	• store in properly designated areas • work in well-ventilated areas • avoid heating • avoid sparks and flames • ensure that electrical sources are safe
Class C: *Oxidizing Materials* Materials that can cause other materials to burn or support combustion		• can cause skin or eye burns • increase fire and explosion hazards • may cause combustibles to explode or react violently	• store away from combustibles • wear body, hand, face, and eye protection • store in proper container that will not rust or oxidize
Class D: *Toxic Materials Immediate and Severe* Poisons and potentially fatal materials that cause immediate and severe harm		• may be fatal if ingested or inhaled • may be absorbed through the skin • small volumes have a toxic effect	• avoid breathing dust or vapours • avoid contact with skin or eyes • wear protective clothing, and face and eye protection • work in well-ventilated areas and wear breathing protection
Class D: *Toxic Materials Long Term Concealed* Materials that have a harmful effect after repeated exposures or over a long period		• may cause death or permanent injury • may cause birth defects or sterility • may cause cancer • may be sensitizers causing allergies	• wear appropriate personal protection • work in a well-ventilated area • store in appropriate designated areas • avoid direct contact • use hand, body, face, and eye protection • ensure respiratory and body protection is appropriate for the specific hazard
Class D: *Biohazardous Infectious Materials* Infectious agents or a biological toxin causing a serious disease or death		• may cause anaphylactic shock • includes viruses, yeasts, moulds, bacteria, and parasites that affect humans • includes fluids containing toxic products • includes cellular components	• special training is required to handle materials • work in designated biological areas with appropriate engineering controls • avoid forming aerosols • avoid breathing vapours • avoid contamination of people and/or area • store in special designated areas
Class E: *Corrosive Materials* Materials that react with metals and living tissue		• eye and skin irritation on exposure • severe burns/tissue damage on longer exposure • lung damage if inhaled • may cause blindness if contacts eyes • environmental damage from fumes	• wear body, hand, face, and eye protection • use breathing apparatus • ensure protective equipment is appropriate • work in a well-ventilated area • avoid all direct body contact • use appropriate storage containers and ensure proper non-venting closures
Class F: *Dangerously Reactive Materials* Materials that may have unexpected reactions		• may react with water • may be chemically unstable • may explode if exposed to shock or heat • may release toxic or flammable vapours • may vigorously polymerize • may burn unexpectedly	• handle with care, avoiding vibration, shocks, and sudden temperature changes • store in appropriate containers • ensure storage containers are sealed • store and work in designated areas

B2 Safety in the Laboratory

General Safety Rules

Safety in the laboratory is an attitude and a habit more than it is a set of rules. It is easier to prevent accidents than to deal with the consequences of an accident. Most of the following rules are common sense:

- Do not enter a laboratory unless a teacher or other supervisor is present, or you have permission to do so.
- Familiarize yourself with your school's safety regulations.
- Make your teacher aware of any allergies and other health problems you may have.
- Wear eye protection, lab aprons or coats, and gloves when appropriate.
- Wear closed shoes (not sandals) when working in the laboratory.
- Place your books and bags away from the work area. Keep your work area clear of all materials except those that you will use in the investigation.
- Do not chew gum, eat, or drink in the laboratory. Food should not be stored in refrigerators in laboratories.
- Know the location of MSDS information, exits, and all safety equipment, such as the fire blanket, fire extinguisher, and eyewash station.
- Avoid sudden or rapid motion in the laboratory that may interfere with someone carrying or working with chemicals or using sharp instruments.
- Never engage in horseplay or practical jokes in the laboratory.
- Ask for assistance when you are not sure how to do a procedural step.
- Never attempt any unauthorized experiments.
- Never work in a crowded area or alone in the laboratory.
- Always wash your hands with soap and water before and after you leave the laboratory. Definitely wash your hands before you touch any food.
- Use stands, clamps, and holders to secure any potentially dangerous or fragile equipment that could be tipped over.
- Do not taste any substance in a laboratory.
- Never smell chemicals unless specifically instructed to do so by the teacher. Do not inhale the vapours, or gas, directly from the container. Take a deep breath to fill your lungs with air, then waft or fan the vapours toward your nose.
- Clean up all spills, even water spills, immediately.
- If you are using a microscope with a mirror, never direct the mirror to sunlight. The concentrated reflected light could hurt your eyes badly.
- Do not forget safety procedures when you leave the laboratory. Accidents can also occur outdoors, at home, and at work.

Eye and Face Safety

- Always wear approved eye protection in a laboratory, no matter how simple or safe the task appears to be. Keep the safety glasses over your eyes, not on top of your head. For certain experiments, full face protection may be necessary.
- If you must wear contact lenses in the laboratory, be extra careful; whether or not you wear contact lenses, do not touch your eyes without first washing your hands. If you do wear contact lenses, make sure that your teacher is aware of it. Carry your lens case and a pair of glasses with you.
- Do not stare directly at any bright source of light (e.g., a burning magnesium ribbon, lasers, the Sun). You will not feel any pain if your retina is being damaged by intense radiation. You cannot rely on the sensation of pain to protect you.
- Never look directly into the opening of flasks or test tubes.

Handling Glassware Safely

- Never use glassware that is cracked or chipped. Give such glassware to your teacher or dispose of it as directed. Do not put the item back into circulation.
- Never pick up broken glassware with your fingers. Use a broom and dustpan.
- Do not put broken glassware into garbage containers. Dispose of glass fragments in special containers marked "Broken Glass."
- Heat glassware only if it is approved for heating. Check with your teacher before heating any glassware.
- Be very careful when cleaning glassware. There is an increased risk of breakage from dropping when the glassware is wet and slippery.

- If you need to insert glass tubing or a thermometer into a rubber stopper, get a cork borer of a suitable size. Insert the borer in the hole of the rubber stopper, starting from the small end of the stopper. Once the borer is pushed all the way through the hole, insert the tubing or thermometer through the borer. Ease the borer out of the hole, leaving the tubing or thermometer inside. To remove the tubing or thermometer from the stopper, push the borer from the small end through the stopper until it shows at the other end. Ease the tubing or thermometer out of the borer.
- Protect your hands with heavy gloves or several layers of cloth before inserting glass into rubber stoppers.

Using Sharp Instruments Safely

- Make sure your instruments are sharp. Surprisingly, one of the main causes of accidents with cutting instruments is using a dull instrument. Dull cutting instruments require more pressure than sharp instruments and are, therefore, much more likely to slip.
- Always transport a scalpel in a dissection case or box. Never carry the scalpel from one area of the laboratory to another with an exposed blade.
- Select the appropriate instrument for the task. Never use a knife when scissors would work best.
- Always cut away from yourself and others.

Fire Safety

- Immediately inform your teacher of any fires. Very small fires in a container may be extinguished by covering the container with a wet paper towel or a ceramic square to cut off the supply of air. Alternatively, sand may be used to smother small fires. A bucket of sand with a scoop should be available in the laboratory.
- If anyone's clothes or hair catch fire, tell the person to drop to the floor and roll. Then use a fire blanket to help smother the flames. Never wrap the blanket around a person on fire; the chimney effect will burn the lungs. For larger fires, immediately evacuate the area. Call the office or sound the fire alarm if close by. Do not try to extinguish larger fires. Your prime concern is to save lives. As you leave the classroom, make sure that the windows and doors are closed.
- If you use a fire extinguisher, direct the extinguisher at the base of the fire and use a sweeping motion, moving the extinguisher nozzle back and forth across the front of the fire's base. Different extinguishers are effective for different classes of fires. The fire classes are outlined below. Fire extinguishers in the laboratory are 2A10BC. They extinguish classes A, B, and C fires.
- Class A fires involve ordinary combustible materials that leave coals or ashes, such as wood, paper, or cloth. Use water or dry chemical extinguishers on class A fires.
- Class B fires involve flammable liquids such as gasoline or solvents. Carbon dioxide or dry chemical extinguishers are effective on class B fires.
- Class C fires involve live electrical equipment, such as appliances, photocopiers, computers, or laboratory electrical apparatus. Carbon dioxide or dry chemical extinguishers are recommended for class C fires. Do not use water on live electrical devices as this can result in severe electrical shock.
- Class D fires involve burning metals, such as sodium, potassium, magnesium, or aluminum. Sand, salt, or graphite can be used to put out class D fires. Do not use water on a metal fire as this can cause a violent reaction.
- Class E fires involve a radioactive substance. These require special consideration at each site.

Heat Safety

- Keep a clear workplace when performing experiments with heat.
- Make sure that heating equipment, such as the burner, hot plate, or electric heater, is secure on the bench and clamped in place when necessary.
- Do not use a laboratory burner near wooden shelves, flammable liquids, or any other item that is combustible.
- Take care that the heat developed by the heat source does not cause any material close by to get hot enough to burst into flame. Do not allow overheating if you are performing an experiment in a closed area. For example, if you are using a light source in a large cardboard box, be sure you have enough holes at the top of the box and on the sides to dissipate heat.
- Before using a laboratory burner, make sure that long hair is always tied back. Do not wear loose clothing (wide long sleeves should be tied back or rolled up).

- Always assume that hot plates and electric heaters are hot and use protective gloves when handling.
- Do not touch a light source that has been on for some time. It may be hot and cause burns.
- In a laboratory where burners or hot plates are being used, never pick up a glass object without first checking the temperature by lightly and quickly touching the item, or by placing your hand near but not touching it. Glass items that have been heated stay hot for a long time, even if they do not appear to be hot. Metal items such as ring stands and hot plates can also cause burns; take care when touching them.
- Never look down the barrel of a laboratory burner.
- Always pick up a burner by the base, never by the barrel.
- Never leave a lighted burner unattended.
- Any metal powder can be explosive. Do not put these in a flame.
- When heating a test tube over a laboratory burner, use a test-tube holder and a spurt cap. Holding the test tube at an angle, with the open end pointed away from you and others, gently move the test tube back and forth through the flame.
- To heat a beaker, put it on the hot plate and secure with a ring support attached to a utility stand. (A wire gauze under the beaker is optional.)
- Remember to include a cooling time in your experiment plan; do not put away hot equipment.

To use a burner:

- Tie back long hair and tie back or roll up wide long sleeves.
- Secure the burner to a stand using a metal clamp.
- Check that the rubber hose is properly connected to the gas valve.
- Close the air vents on the burner. Use a sparker to light the burner.
- Open the air vents just enough to get a blue flame.
- Control the size of the flame using the gas valve.

Electrical Safety

- Water or wet hands should never be used near electrical equipment such as a hotplate, a light source, or a microscope.
- Do not use the equipment if the cord is frayed or if the third pin on the plug is missing. If the teacher allows this, then make sure the equipment has a double-insulated cord.
- Do not operate electrical equipment near running water or a large container of water.
- Check the condition of electrical equipment. Do not use if wires or plugs are damaged.
- If using a light source, check that the wires of the light fixture are not frayed, and that the bulb socket is in good shape and well secured to a stand.
- Make sure that electrical cords are not placed where someone could trip over them.
- When unplugging equipment, remove the plug gently from the socket. Do not pull on the cord.

Handling Chemicals Safely

Many chemicals are hazardous to some degree. When using chemicals, operate under the following principles:

- Never underestimate the risks associated with chemicals. Assume that any unknown chemicals are hazardous.
- Use a less hazardous chemical wherever possible.
- Reduce exposure to chemicals as much as possible. Avoid direct skin contact if possible.
- Ensure that there is adequate ventilation when using chemicals.

The following guidelines do not address every possible situation but, used with common sense, are appropriate for situations in the high school laboratory.

- Obtain an MSDS for each chemical and consult the MSDS before you use the chemical.
- Know the emergency procedures for the building, the department, and the chemicals being used.
- Wear a lab coat and/or other protective clothing (e.g., apron, gloves), as well as appropriate eye protection at all times in areas where chemicals are used or stored.
- Never use the contents from a bottle that has no label or has an illegible label. Give any containers with illegible labels to your teacher. When leaving chemicals in containers, ensure that the containers are labelled. Always double-check the label, once, when you pick it up, and a second time when you are about to use it.
- Carry chemicals carefully using two hands, one around the container and one underneath.
- Always pour from the side opposite the label on a reagent bottle; your hands and the label are protected

as previous drips are always on the side of the bottle opposite of the label.

- Do not let the chemicals touch your skin. Use a laboratory scoop or spatula for handling solids.
- Pour chemicals carefully (down the side of the receiving container or down a stirring rod) to ensure that they do not splash.
- Always pour volatile chemicals in a fume hood or in a well-ventilated area.
- Never pipet or start a siphon by mouth. Always use a pipet suction device (such as a bulb or a pump).
- If you spill a chemical, use a chemical spill kit to clean up.
- Return chemicals to their proper storage place according to your teacher's instructions.
- Do not return surplus chemicals to stock bottles. Dispose of excess chemicals in an appropriate manner as instructed by your teacher.
- Clean up your work area, the fume hood, and any other area where chemicals were used.
- Wash hands immediately after handling chemicals and before and after leaving the lab, even if you wore gloves. Definitely wash your hands before you touch any food.

Handling Animals, Plants, and Other Organisms Safely

- Do not perform any investigation on any animal that might cause suffering or pain, or that might pose a health hazard to you or anyone else in the school.
- Animals that live in the classroom should be treated with care and respect, and be kept in a clean, healthy environment.
- Ensure that your teacher is aware of any plant or animal allergies that you may have.
- Never bring a plant, animal, or other organism to school without receiving prior permission from the teacher.
- Keep cages and tanks clean—both for your health and the health of the organism. Most jurisdictions recommend no live mammals or birds in the laboratory. Reptiles often carry Salmonella.
- Wear gloves and wash your hands before and after feeding or handling an animal, touching materials from the animal's cage or tank, or handling bacterial cultures.
- Do not grow any microorganisms other than those that occur naturally on mouldy bread, cheese, and mildewed objects. Anaerobic bacteria should not be grown.
- Cultures should be grown at room temperature or in the range of 25 °C to 32 °C. Incubation at 37 °C may encourage the growth of microorganisms that are capable of living in the human body.
- Bacteria from soils should not be grown because of the possibility of culturing tetanus-causing organisms.
- Spores collected from household locations, such as telephones or bathrooms, should not be cultured in the laboratory. The body can destroy small numbers of these bacteria, but may not be able to cope with large numbers.
- All surfaces and equipment used in culturing microorganisms should be washed down with a disinfectant (e.g., a solution of bleach).
- Apparatus used in microbiology should be autoclaved because liquid disinfectants and germicidal agents generally cannot guarantee complete sterilization. The oven of an ordinary kitchen stove may be used.
- Wild or sick animals should never be brought into the lab. Dead animals, wild or tame, that have died from unknown causes should also not be brought into the lab.
- Preserved specimens should be removed from the preservative with gloves or tongs, and rinsed thoroughly in running water.
- Before going on field trips, become familiar with any dangerous plants and animals that may be common in the area (e.g., stinging nettles and poisonous plants).

Waste Disposal

Waste disposal at school, at home, and at work is a societal issue. To protect the environment, federal and provincial governments have regulations to control wastes, especially chemical wastes. For example, the WHMIS program applies to controlled products that are being handled. Most laboratory waste can be washed down the drain or, if it is in solid form, placed in ordinary garbage containers. However, some waste must be treated more carefully. It is your responsibility to follow procedures and to dispose of waste in the safest possible manner according to the teacher's instructions.

Flammable Substances

Flammable liquids should not be washed down the drain. Special fire-resistant containers are used to store flammable liquid waste. Waste solids that pose a fire hazard should be stored in fireproof containers. Care must be taken not to allow flammable waste to come into contact with any sparks, flames, other ignition sources, or oxidizing materials. The method of disposal depends on the nature of the substance.

Corrosive Solutions

Solutions that are corrosive but not toxic, such as acids, bases, and oxidizing agents, should be disposed of in a container provided by the teacher, preferably kept on the teacher's desk. Do not pour corrosive solutions down the drain.

Toxic Substances

Solutions of toxic substances should not be poured down the drain, in order to keep them out of the environment. A special container should be kept in the laboratory for toxic substances and disposed by a teacher, according to the regulations of your area.

Organic Material

Remains of plants and animals can generally be disposed of in school garbage containers. Before disposal, organic material should be rinsed thoroughly to rid it of any excess preservative. Fungi and bacterial cultures should be autoclaved or treated with a fungicide or antibacterial soap before disposal.

First Aid

The following guidelines apply in case of an injury, such as a burn, cut, chemical spill, ingestion, inhalation, or splash in the eyes.

- Always inform your teacher immediately of any injury.
- Know the location of the first-aid kit, fire blanket, eyewash station, and shower, and be familiar with the contents and operation of them.
- If the injury is a minor cut or abrasion, wash the area thoroughly. Using a compress, apply pressure to the cut to stop the bleeding. When bleeding has stopped, replace the compress with a sterile bandage. If the cut is serious, apply pressure and seek medical attention immediately.
- If the injury is the result of chemicals, drench the affected area with a continuous flow of water for 15 min. Clothing should be removed as necessary. Retrieve the Material Safety Data Sheet (MSDS) for the chemical; this sheet provides information about the first-aid requirements for the chemical.
- If you get a solution in your eye, quickly use the eyewash or nearest running water. Continue to rinse the eye with water for at least 15 min. This is a very long time—have someone time you. Unless you have a plumbed eyewash system, you will also need assistance in refilling the eyewash container. Have another student inform your teacher of the accident. The injured eye should be examined by a doctor.
- If you have ingested or inhaled a hazardous substance, inform your teacher immediately. The MSDS provides information about the first-aid requirements for the substance. Contact the Poison Control Centre in your area.
- If the injury is from a burn, immediately immerse the affected area in cold water or run cold water gently over the burned area. This will reduce the temperature and prevent further tissue damage.
- In case of electric shock, unplug the appliance and do not touch it or the victim. Inform your teacher immediately.
- If a classmate's injury has rendered him/her unconscious, notify the teacher immediately. The teacher will perform CPR if necessary. Do not administer CPR unless under specific instructions from the teacher. You can assist by keeping the person warm and by reassuring him/her once conscious.

C1 Numerical Prefixes and Units

Throughout *Nelson Biology Alberta 20-30* and in this reference section, we have attempted to be consistent in the presentation and usage of units. As far as possible, *Nelson Biology Alberta 20-30* uses the International System (SI) of Units. However, some other units have been included because of their practical importance, wide usage, or use in specialized fields. For example, Health Canada and the medical profession continue to use millimetres of mercury (mmHg) as the units for measurement of blood pressure, although the Metric Practice Guide indicates that this unit is not to be used with the SI.

The most recent *Canadian Metric Practice Guide* (CAN/CSA-Z234.1-89) was published in 1989 and reaffirmed in 1995 by the Canadian Standards Association.

Other data in this reference section has been taken largely from Lange's *Handbook of Chemistry*, Fifteenth Edition, McGraw-Hill, 1999.

Numerical Prefixes

Prefix	Power	Symbol
deca-	10^{1}	da
hecto-	10^{2}	h
kilo-	10^{3}	k*
mega-	10^{6}	M*
giga-	10^{9}	G*
tera-	10^{12}	T
peta-	10^{15}	P
exa-	10^{18}	E
deci-	10^{-1}	d
centi-	10^{-2}	c*
milli-	10^{-3}	m*
micro-	10^{-6}	m*
nano-	10^{-9}	n*
pico-	10^{-12}	p
femto-	10^{-15}	f
atto-	10^{-18}	a

* commonly used

Common Multiples

Multiple	Prefix
0.5	hemi–
1	mono–
1.5	sesqui–
2	bi–, di–
2.5	hemipenta–
3	tri–
4	tetra–
5	penta
6	hexa
7	hepta–
8	octa
9	nona–
10	deca–

Some Examples of Prefix Use

0.0034 mol = 3.4×10^{-3} mol = 3.4 **milli**moles or 3.4 mmol
1530 L = 1.53×10^{3} L = 1.53 **kilo**litres or 1.53 kL

SI Base Units

Quantity	Symbol	Unit name	Symbol
amount of substance	n	mole	mol
electric current	I	ampere	A
length	L, l, h, d, w	metre	m
luminous intensity	I_v	candela	cd
mass	m	kilogram	kg
temperature	T	kelvin	K
time	t	second	s

Some SI Derived Units

Quantity	Symbol	Unit	Unit Symbol	Expression in SI base unit
acceleration	$\vec{a}$	metre per second per second	m/s^2	m/s^2
area	A	square metre	m^2	m^2
density	ρ, D	kilogram per cubic metre	kg/m^3	kg/m^3
displacement	$\vec{d}$	metre	m	m
electric charge	Q, q, e	coulomb	C	A·s
electric potential	V	volt	V	$kg{\cdot}m^2/(A{\cdot}s^3)$
electric field	E	volt per metre	V/m	$kg{\cdot}m/(A{\cdot}s^3)$
electric field intensity	E	newton per coulomb	N/C	$kg/(A{\cdot}s^3)$
electric resistance	R	ohm	Ω	$kg{\cdot}m^2/(A^2{\cdot}s^3)$
energy	E, E_k, E_p	joule	J	$kg{\cdot}m^2/s^2$
force	F	newton	N	$kg{\cdot}m/s^2$
frequency	f	hertz	Hz	s^{-1}
heat	Q	joule	J	$kg{\cdot}m^2/s^2$
magnetic flux	Φ	weber	Wb	$kg{\cdot}m^2/(A{\cdot}s^2)$
magnetic field	B	weber per square metre Tesla	Wb/m^2 T	$kg/(A{\cdot}s^2)$
momentum	P, p	kilogram metre per second	kg·m/s	kg·m/s
period	T	second	s	s
power	P	watt	W	$kg{\cdot}m^2/s^3$
pressure	P p	pascal newton per square metre	Pa N/m^2	$kg/(m{\cdot}s^2)$
speed	v	metre per second	m/s	m/s
velocity	$\vec{v}$	metre per second	m/s	m/s
volume	V	cubic metre	m^3	m^3
wavelength	λ	metre	m	m
weight	W, w	newton	N	$kg{\cdot}m/s^2$
work	W	joule	J	$kg{\cdot}m^2/s^2$

C2 Greek and Latin Prefixes and Suffixes

Greek and Latin Prefixes

Prefix	Meaning	Prefix	Meaning	Prefix	Meaning
a-	not, without	em-	inside	micr-, micro-	small
ab-	away from	en-	in	mono-	one
abd-	led away	end-, endo-	within	morpho-	form, shape
acro-	end, tip	epi-	at, on, over	muc-, muco-	slime
adip-	fat	equi-	equal	multi-	many
aer-, aero-	air	erythro-	red	myo-	muscle
agg-	to clump	ex-, exo-	away, out	nas-	nose
agro-	land	flag-	whip	necro-	corpse
alb-	white	gamet-, gamo-	marriage, united	neo-	new
allo-	other	gastr-, gastro-	stomach	neur-, neuro-	nerve
ameb-	change	geo-	earth	noct-	night
amphi-	around, both	glyc-	sweet	odont-, odonto-	tooth
amyl-	starch	halo-	salt	oligo-	few
an-	without	haplo-	single	oo-	egg
ana-	up	hem-, hema-, hemato-	blood	orni-	bird
andro-	man	hemi-	half	oss-, osseo-, osteo-	bone
ant-, anti-	opposite	hepat-, hepa-	liver	ovi-	egg
anth-	flower	hetero-	different	pale-, paleo-	ancient
archae-, archaeo-	ancient	histo-	web	patho-	disease
archi-	primitive	holo-	whole	peri-	around
astr-, astro-	star	homeo-	same	petro-	rock
aut-, auto-	self	hydro-	water	phag-, phago-	eat
baro-	weight (pressure)	hyper-	above	pharmaco-	drug
bi-	twice	hypo-	below	phono-	sound
bio-	life	infra-	under	photo-	light
blast-, blasto-	sprout (budding)	inter-	between	pneum-	air
carcin-	cancer	intra-	inside of, within	pod-	foot
cardio-, cardia-	heart	intro-	inward	poly-	many
chlor-, chloro-	green	iso-	equal	pseud-, pseudo-	false
chrom-, chromo-	colour	lact-, lacti-, lacto-	milk	pyr-, pyro-	fire
co-	with	leuc-, leuco-	white	radio-	ray
cosmo-	order, world	lip-, lipo-	fat	ren-	kidney
cut-	skin	lymph-, lympho-	clear water	rhizo-	root
cyan-	blue	lys-, lyso-	break up	sacchar-, saccharo-	sugar
cyt-, cyto-	cell	macro-	large	sapr-, sapro-	rotten
dendr-, dendri-, dendro-	tree	mamm-	breast	soma-	body
dent-, denti-	tooth	meg-, mega-	great	spermato-	seed
derm-	skin	melan-	black	sporo-	seed
di-	two	meningo-	membrane	squam-	scale
dors-	back	mes-, meso-	middle	sub-	beneath
ec-, ecto-	outside	meta-	after, transition	super-, supra-	above

Greek and Latin Prefixes *(continued)*

Prefix	Meaning	Prefix	Meaning	Prefix	Meaning
sym-, syn-	with, together	ultra-	beyond	xanth-, xantho-	yellow
telo-	end	uro-	tail, urine	xer-, xero-	dry
therm-, thermo-	temperature, heat	vas-, vaso-	vessel	xyl-	wood
tox-	poison	vita-	life	zoo-	animal
trans-	across	vitro-	glass	zygo-	yoke
trich-	hair	vivi-	alive		

Greek and Latin Suffixes

Suffix	Meaning	Suffix	Meaning	Suffix	Meaning
-aceous	like	-lysis	loosening	-phyll	leaf
-blast	budding	-lyt	dissolvable	-phyte	plant
-cide	kill	-mere	share	-pod	foot
-crin	secrete	-metry	measure	-sis	a condition
-cut	skin	-mnesia	memory	-some	body
-cyte	cell	-oid	like	-stas, -stasis	halt
-emia	blood	-ol	alcohol	-stat	to stand, stabilize
-gen	born, agent	-ole	oil	-tone, -tonic	strength
-genesis	formation	-oma	tumour	-troph	nourishment
-graph, -graphy	to write	-osis	a condition	-ty	state of
-gynous	woman	-pathy	suffering	-vorous	eat
-itis	inflammation	-ped	foot	-yl	wood
-logy	the study of	-phage	eat	-zyme	ferment

C3 Data for Some Radioisotopes

Name	Symbol	Uses	Half-life
carbon-14	^{14}C	radiometric dating—effective dating range: 100 to 100 000 years	5730 years
fluorine-18	^{18}F	medical—to image tumours and localized infections (PET)	110 minutes
indium-111	^{111}In	medical—to study the brain, the colon, and sites of infection	2.8 days
iodine-125	^{125}I	medical—to evaluate the filtration rate of kidneys and to determine bone density measurements	42 days
iodine-131	^{131}I	medical—to view and treat thyroid, liver, kidney diseases, and various cancers	8.0 days
phosphorus-32	^{32}P	medical—to treat polycythemia vera (excess red blood cells)	14.3 days
potassium-40	^{40}K	radiometric dating—effective dating range: 100 000 to 4.6 billion years	1.3 billion years
strontium-89	^{89}Sr	medical—to relieve the pain of secondary cancers lodged in the bone	46.7 hours
technetium-99*	^{99}Tc	medical—to view the skeleton and heart muscle in particular; but also the brain, thyroid, lungs, liver, spleen, kidney, gall bladder, bone marrow, and salivary glands	6.02 hours
uranium-235	^{235}U	radiometric dating—effective dating range: 10 million to 4.6 billion years	713 million years

* the most commonly used isotope in medicine

C4 RNA Codons and Amino Acids

The codons in mRNA are nucleotide bases arranged in groups of three. There are 61 of these base triplets that correspond to 20 amino acids. In **Table 1**, read the first nucleotide from the first (left) column, the second from one of the middle columns, and the third from the last (right) column. For example, the triplet UGG represents tryptophan, and tyrosine is represented by both UAU and UAC. mRNA reads the arrangements of amino acids on the DNA and carries the information to the ribosomes for the synthesis of proteins.

Table 1: Messenger Ribonucleic Acid (mRNA) Codons and Their Corresponding Amino Acids

First Base	Second Base				Third Base
	U	C	A	G	
U	UUU phenylalanine UUC phenylalanine UUA leucine UUG leucine	UCU serine UCC serine UCA serine UCG serine	UAU tyrosine UAC tyrosine UAA STOP** UAG STOP**	UGU cysteine UGC cysteine UGA STOP** UGG tryptophan	**U** **C** **A** **G**
C	CUU leucine CUC leucine CUA leucine CUG leucine	CCU proline CCC proline CCA proline CCG proline	CAU histidine CAC histidine CAA glutamine CAG glutamine	CGU arginine CGC arginine CGA arginine CGG arginine	**U** **C** **A** **G**
A	AUU isoleucine AUC isoleucine AUA isoleucine AUG methionine*	ACU threonine ACC threonine ACA threonine ACG threonine	AAU asparagine AAC asparagine AAA lysine AAG lysine	AGU serine AGC serine AGA arginine AGG arginine	**U** **C** **A** **G**
G	GUU valine GUC valine GUA valine GUG valine	GCU alanine GCC alanine GCA alanine GCG alanine	GAU aspartate GAC aspartate GAA glutamate GAG glutamate	GGU glycine GGC glycine GGA glycine GGG glycine	**U** **C** **A** **G**

* AUG is an initiator codon and also codes for the amino acid methionine.
** UAA, UAG, and UGA are terminator codons.

Answers

Unit 20 A

Section 1.1, p. 10

1. both closed systems
2. no outside source of raw material
3. abiotic—non-living; biotic—living
4. community—all populations; ecosystem—community plus its environment
5. organism, population, community, ecosystem
7. (a) variety of species in an ecosystem
   (b) mitochondria
   (c) high–Grand Banks, north shore of Lake Erie; low–Arctic Ocean, taiga ecosystems

Section 1.2, p. 16

3. (a) lives in freshwater and forest ecosystems; skin vulnerable to pollutants
5. (b) preserve habitat for organisms at risk

Chapter 1 Review, pp. 18–19

9. (a) bounties—reduced wolf populations led to increased deer populations
   (b) hunting—reduced bison; overfishing reduced cod and salmon
   (c) increase in sea urchins led to reduction in kelp and fish
10. doubtful if the species will survive without intervention
11. (a) extinct, endangered, extirpated, threatened, vulnerable
12. (a) threatened
    (b) endangered
    (c) extirpated
15. (a) Cockroaches are scavengers that lives off garbage.

Section 2.1, p. 27

1. the position of a species on a food chain
2. eats primary consumers (meat)
3. food chain—single path; food web—multiple interwoven pathways
4. reactants—CO_2, H_2O, energy; products—O_2, glucose
5. reactants—O_2, glucose; products—CO_2, H_2O, energy
6. inorganic chemicals—hydrogen sulphide, ammonia, ferrous ions, sulfur
8. 90 % of energy required for processes such as, photosynthesis, growth, and reproduction

Practice, p. 31

1. 1st—10 cm^2 or 100cm^3; 2nd —980 cm^2 or 9800cm^3; 3rd—50 cm^2 or 500 mm^3; 4th—1 cm^2 or 10 cm^3; 5th—0.3 cm^2 or 3 cm^3

Practice, p. 32

2. plankton—200 cm^2; zooplankton—20 cm^2; herring—2 cm^2; salmon—0.2 cm^2
3. (a) 200 rabbits
   (b) 10 foxes
   (c) plants—100 cm^2 or 1000 cm^3; rabbits—20 cm^2 or 20 cm^3; foxes—1 cm^2 or 10 mm^3

Section 2.2. p. 34

1. population size of all organisms
2. does not show energy flow
5. energy flow in ecosystems obeys laws of thermodynamics; energy lost at each level
6. plant tissue
7. 150 000 kJ
8. (a) 1.5×10^6 kJ
   (b) 1st—200 cm^2; 2nd—20 cm^2; 3rd—2 cm^2; 4th—0.2cm^2

Chapter 2 Review, pp. 38–39

4. eats lower-order consumers; is not eaten by other organisms
10. 1, 2, 4—not sustainable; 3—is sustainable
14. energy assimilated by chemoautotrophs
16. (a) middle-latitude woodland ecosystem
    (b) middle-latitude woodland ecosystem
    (c) middle-latitude woodland ecosystem
19. pyramid of energy
20. 4th—100 kJ; 5th—10 kJ, insufficient to maintain a carnivore
22. producer—they convert light energy into chemical energy
24. (a) kelp → sea urchins → sea otters
    (b) reduce the kelp
    (c) decreased barnacles and mussels
25. introduced tropical fishes; chlorine leaking from swimming pool; beaver dam

Section 3.1, p. 48

1. (a) C and H
   (b) through breathing
   (c) food (in animals); roots (in plants)
   (d) breathing; excreting; decay after death
4. to determine if life has ever existed there
6. no bacteria to recycle the organic matter
7. most metabolic reactions require H_2O
9. highest level belowground that is saturated with H_2O

Section 3.2, p. 59

1. They release C from dead organisms.
3. releases C stored in peat, coal, natural gas, petroleum
4. (a) fewer plants; slower rate of photosynthesis; plants are dormant in winter
5. (a) entering—232×10^{13} kg; leaving—227×10^{13} kg.; increasing at 5×10^{13} kg per year
   (c) atmospheric O_2—photosynthesis produces O_2 as a by-product
6. (a) reduces atmospheric O_2—photosynthesis is reduced
   (b) more difficult for plants and animals to carry on respiration

Section 3.3, p. 66

1. Nutrients are stored in the crops.
3. (a) Spring runoff contains nitrates and nitrites.
5. green manure
6. used to produce proteins and nucleic acids
7. must be converted into nitrates before it can be used by organisms
8. consume dead organic matter
9. bacteria converts N to nitrates for plant; plant provide sugar to bacteria
11. exposes denitrifying bacteria to O_2
12. ADP, ATP, cell membranes, DNA molecules, bones
13. fix N improving soil quality
14. lack N-fixing bacteria and organism that aerate the soil
16. (a) 3—low soil nitrates, high biomass nitrates
    (b) 1 grassland—high soil temperature and biomass nitrates
    2 temperate rainforest—low soil temperature and high biomass nitrates
    3 tropical rainforest—high soil temperature and high biomass nitrates
    (c) low soil and biomass nitrate; low soil temperature
18. ammonia, nitrates, nitrites pollute groundwater

19. both water soluble; taken up by plant roots to enter the food chain

Chapter 3 Review, pp. 73–75

7. cycling of materials through the biosphere
16. May—70 %; August—20 %
17. willow
18. balsam poplar—47 % loss
19. temperature
20. arrival of insects; increase in bacteria
22. energy flows through an ecosystem; nutrients are recycled
24. manipulated—distance to light; responding—number O_2 bubbles
25. light, size and species of plant; amount and temperature of water
27. Fire returns nutrients and minerals to the soil.
29. (a) photosynthesis, respiration
32. O_2 solubility increases as temperatures decrease.

Unit 20 A Review, pp. 76–79

38. How can transpiration be measured?
39. leaf number, size; amount of sunlight
41. decrease
42. reduced surface area, leaf number, stomata number; cuticle; hairs

Unit 20 B

4.1 Practice, p. 86

1. study of all interactions in the biosphere
2. population—one species; community—many populations
3. ecosystem is the community plus biotic and abiotic components

Section 4.1, p. 93

2. ecotone—organisms from both ecosystems found there
4. organism's role in food web and abiotic and biotic requirements

4.2 Practice, p. 98

1. layer of frozen soil that doesn't melt in summer
2. muskeg—poor drainage, short growing season, cool temperatures; grassland—warm temperatures, rapid nutrient cycling
3. adapted to moist, acidic soils and cooler temperatures
4. too arid

Section 4.2, p. 100

2. waxy needles, pyramid shaped, flexible branches
3. (a) deciduous forest > taiga > muskeg > grassland
   (b) grassland > deciduous forest > taiga > muskeg
   (c) grassland > deciduous forest > taiga > muskeg
   (d) deciduous forest > grassland > taiga > muskeg

4.3 Practice, p. 104

2. depth and type of the bedrock, precipitation

Section 4.3, p. 107

1. fertilizers, sewage emissions, litter from plants, animal wastes, die-off

Section 4.4, pp. 111–112

1. biotic potential, limiting factors, carrying capacity, limits of tolerance
2. (a) increase carrying capacity
   (b) falcons are feeding the waxwings; falcon attracted to feeders
3. (a) increase in the moose population
   (b) wolf population should recover; population size will fluctuate
   (c) when biotic or abiotic conditions become favourable
5. (a) C—causes steady decline in beetles
   (b) D—beetle increases and D decreases
   (c) each predator eats many prey
   (d) population would crash; surviving beetles help population rebound

4.5 Practice, p. 115

1. recycle H_2O and CO_2; prevent soil erosion
2. slash and burn, clear-cutting, selective cutting
3. decrease biodiversity, wind and water erosion, deplete soil nutrients

4.5 Practice, p. 118

4. organic solid waste, thermal energy, organic chemicals
5. warm lake—more productive
6. fertilizer run off, run off of organic salts from roads

4.5 Practice, p. 120

7. removing plants, making a sandy beach, planting lawns
8. increase runoff of harmful substances, increase water temperature
9. positive—reduce economic and ecological costs; negative—affect water cycle

Section 4.5, p. 122

4. (a) decreases
   (b) deeper lakes are cooler
   (c) higher lake temperatures lead to greater littoral zone diversity
   (e) eat plants found in 2nd stage
5. (a) sewage-treatment plant
   (b) B—nitrate and phosphate levels are highest
   (c) more organisms live at B; they consume O_2
   (d) C—fewer nutrients; fewer organisms consuming O_2
   (e) no—drop in dissolved O_2; high nutrient load

Chapter 4 Review, pp. 130–133

9. algae, fescue grass
10. wet, muddy, and windy
11. both pond and grassland species present
12. likely effect both ecosystems

5.1 Practice, p. 137

2. naming organisms using genus and species
3. provides a common language
4. kingdom, phylum, class, order, family, genus, species

Section 5.1, p. 139

1. illustration showing relations among organisms
2. unified classification system
3. reduces confusion; shows evolutionary relationships
5. Archaebacteria—oldest form of life
6. (a) (vii)
   (b) (i)
   (c) (iv)
   (d) (iii)
   (e) (vi)
   (f) (v)
   (g) (viii)
   (h) (ii)
7. (a) mink, shorttailed weasel, ferret
   (b) muskrat
   (c) chipmunk
   (d) groundhog, chipmunk

5.2 Practice, p. 142

2. method to age rock

Section 5.2, p. 143

1. (a) older fossils—less complex, lower diversity
2. remote island—less gene flow

5.3 Practice, p. 145

1. analogous

Section 5.3, p. 149

4. evolutionary rate is quite fast

Section 5.4, p. 152

1. (a) selection against large males
   (b) rate is unchanged

Section 5.5, p. 156

1. unaware of the source of variation

Section 5.6, p. 161

4. distinct species often appear abruptly in fossil record; little further change

Chapter 5 Review, pp. 168–169

13. natural selection
14. all letters have an equal chance of "mutating" in each generation

15. not included in the next generation
16. yes—eventually
18. yes
19. yes
20. no
23. shows how related species differ
24. advantages—accuracy, quantitative; disadvantages—costly, time consuming

Unit 20 B Review, pp. 170–173

19. becomes shallower and warmer
20. sedimentation; lower water table; decreased rainfall; diverted stream
22. decrease O_2—loss of some species
23. lakes becoming colder; continued respiration under ice
24. changing O_2 levels
25. removal of shoreline plants; fertilizers; thermal pollution
26. most economical (short-term); reduces biodiversity, soil erosion, loss of soil nutrients
28. spring and autumn
29. spring—flush of nutrients; autumn—decomposing organic matter
35. sewage—increase BOD, decreased dissolved O_2
39. sexual reproducing species have greater variability

Unit 20 C

6.1 Practice, p. 181

1. plants, plantlike protists, cyanobacteria
2. (a) form of energy that travels at 3×10^8 m/s in the form of photons
   (b) EM wave packets of light

6.1 Practice, p. 182

3. chlorophyll
4. chlorophyll *a*—dark blue and orange; chlorophyll *b*—light blue and dark yellow

Section 6.1, p. 185

1. (a) As wavelength increases, the energy in a photon decreases.
   (b) green light—it has a shorter wavelength
   (c) A higher wavelength has lower energy. Red light is 750 nm; violet is 380 nm.
2. (a) chlorophyll *a*, chlorophyll *b*, carotenoids, xanthophylls, anthocyanins
3. contain the molecule chlorophyll to capture electromagnetic radiation
4. A—thylakoid; B—stroma; C—inner envelope membrane; D—outer envelope membrane

6.2 Practice, p. 187

1. ATP, NADPH, glucose
2. thylakoid membrane of a chloroplast
3. stroma of chloroplasts

6.2 Practice, p. 188

4. thylakoid membrane
5. Electrons gain energy or become excited.
6. replaced by photolysis of water

6.2 Practice, p. 190

7. enter the electron transport chain
9. oxidation—loss of electrons; reduction—gain of electrons
10. They release energy in small amounts.

6.2 Practice, p. 191

11. electrons from photosystem II
12. build up a positive charge inside the lumen
13. used to transfer high-energy electrons to the Calvin cycle
14. process for synthesizing ATP

6.2 Practice, p. 193

15. stroma
16. G3P—used to make glucose

Section 6.2, p. 194

1. adenosine triphosphate—a usable form of chemical energy
2. $6\ CO_2 + 6\ H_2O \rightarrow 6\ O_2 + C_6H_{12}O_6$
3. (a) capture electromagnetic radiation; convert it to chemical potential energy
   (b) thylakoid membranes
   (c) O_2, ATP, NADPH
   (d) Calvin cycle
4. (a) O_2
   (b) H_2O
6. (a) 12
   (b) 36
   (c) 24

Chapter 6 Review, pp. 200–201

11. (a) short wavelengths
    (b) 380 to 480 nm and 620 to 680 nm
14. purple, blue, orange, and red—they are most absorbed by the pigments
15. green—they are the least absorbed
16. chlorophyll *a*
17. Chlorophyll does not absorb green light, it reflects it.
18. chlorophyll *a*, chlorophyll *b*

7.1 Practice, p. 205

1. converts glucose into usable ATP

Section 7.1, p. 209

2. produces waste energy which heats our bodies
4. provides cells with energy for cellular processes
5. glycolysis, pyruvate oxidation, Krebs cycle, electron transport chain and chemiosmosis

Section 7.2, p. 212

1. 1 glucose + 2 ADP + 2 P_i + 2 $NAD^+ \rightarrow$ 2 pyruvate + 2 ATP + 2 NADH + 2 H^+
2. (a) splitting of a glucose molecule into two pyruvate molecules
   (b) 2 pyruvate, 2 NADH, 2 ADP, 4 ATP
3. NADH, 2 pyruvate molecules

7.3 Practice, p. 215

1. Krebs cycle, electron transport chain, chemiosmosis
2. gains 2 H^+ ions and 2 electrons to become NADH
3. joins to acetic acid group to form acetyl-coA

7.3 Practice, p. 219

5. 6 CO_2, 6 H_2O, 36 ATP
6. $FADH_2$, NADH.

Section 7.3, p. 220

2. (a) cytoplasm
   (b) pyruvate, NADH
5. (a) hydrogen
   (d) chemiosmosis
   (e) Peter Mitchell
6. (b) oxygen
7. does not show the formation of energy or that water is required

7.4 Practice, p. 222

2. CO_2
3. (a) 2
   (b) alcoholic fermentation—2; lactic acid fermentation—0
   (c) none

7.4 Practice, p. 226

4. alcohol fermentation—CO_2, ethanol; lactic acid fermentation—lactic acid
5. muscle stiffness, soreness, fatigue

Section 7.4, p. 228

2. build-up of lactic acid
6. (a) 3.0 mmol/L

Chapter 7 Review, pp. 232–233

11. (a) 36
    (b) 2
15. lactic acid
16. allow lactic acid to be converted into pyruvate
18. A—faster growth rate
22. 15 mL/kg/min
23. resting—1125 mL/min; highest VO_2 max—6750 mL/min

Unit 20 C Review, pp. 234–235

16. photosynthesis
17. cellular respiration
18. glucose—accumulate; CO_2—decrease
19. Biomass would increase.

Unit 20 D

8.1 Practice, p. 245

1. provide energy
2. glucose (many foods); fructose (fruit); galactose (milk)

4. They are converted to fat and stored.
5. Sugars end in "ose."
6. They are both polysaccharides; starch is a storage molecule, cellulose is a structural molecule.

8.1 Practice, p. 247

7. compounds of carbon, hydrogen, and oxygen that supply energy to cells
8. fatty acids and glycerol
9. saturated fats—contain no double bonds; unsaturated fats—contain double bonds
10. yes—they carry some important vitamins

Section 8.1, p. 253

1. glucose + fructose = sucrose + H_2O
2. excess of glucose in the blood is converted to glycogen in the liver and stored; can be used for energy
3. holds water and helps eliminate solid waste
4. (a) donkey and horse
   (b) very dissimilar; less similar

Section 8.2, p. 258

1. increase the rates of chemical reactions without high temperatures
2. bring reactants together in the proper configuration, reducing activation energy
3. temperature, pH, substrate concentration, inhibitor molecules
4. They help enzymes combine with substrates.
5. molecules that fit the active site of an enzyme and inhibit the reaction
7. feedback inhibition
10. (a) A—reactants; B—activation energy; C—products
    (b) reaction will slow down
    (c) curve would be flatter
11. (b) rate of reaction would decrease

8.3 Practice, p. 260

1. initiates carbohydrate breakdown (amylase); lubricates food passage; dissolves food particles; activates taste buds
2. breaks food into smaller pieces, increasing surface area for enzyme action
3. initiate the hydrolysis (breakdown) of carbohydrates
4. peristalsis

Section 8.3, p. 263

2. physical—breaks down large particles by chewing; chemical digestion—breaks chemical bonds with enzymes
3. only voluntary action is swallowing
4. (a) carnivores
   (b) herbivores
5. sphincter muscles
6. mucus, hydrochloric acid, pepsinogens
7. protects the cells of the stomach
8. instrument used to view the inside of the body
9. pH, temperature
10. amylase—initiates breakdown of carbohydrates; pepsin—initiates breakdown of protein
11. bacteria, stomach acid
12. They would digest proteins and long-chain peptides even in the absence of food.
13. pH 2.0—stomach; pH 7.0—mouth
14. pH of stomach changes shape of the amylase, making it inactive
15. more tooth decay; acids cause tooth decay

8.4 Practice, p. 266

1. bicarbonate ions buffer HCl
2. trypsinogen and erepsins, amylases, lipases
4. lipase, phospholipase acts on phospholipids; yes
5. bicarbonate ions neutralize HCl in the duodenum inactivating pepsin
6. less absorption; overall food energy intake is reduced
7. lined with villi and microvilli; they increase the surface area for absorption

8.4 Practice, p. 268

8. bile salts and pigments; produced in liver; stored in the gallbladder
9. emulsify fats, providing more surface area for fat-digesting enzymes
10. It is nonpolar.
12. water reabsorption
13. provides bulk

Section 8.4, p. 270

1. must be emulsified; occurs in small intestine; bile salts break up fat
3. both; carbohydrates and amino acids—capillary networks of villi; fats—lacteals
5. seeing or smelling food
7. crystals of precipitated bile salts in the gallbladder
8. yellowish discoloration of tissues caused by a buildup of bile pigments in the blood
9. reduce fat intake

Chapter 8 Review, pp. 278–279

10. soluble in fats (nonpolar solvents) and water (polar solvents) so they can penetrate cell membranes
12. reaction X
13. enzyme is being used at its maximum rate
14. reaction X—curve would rise; reaction Y—line would become steeper
15. reaction would be blocked between R and S

9.1 Practice, p. 283

1. Cells of the body obtain energy through oxidation.
2. breathing—movement of gases between the external environment and the lungs; cellular respiration—the oxidation of glucose in cells of the body, producing ATP
3. diffusion of oxygen and carbon dioxide between the cells and the external environment

9.1 Practice, p. 285

4. remove foreign particles trapped in the mucus that lines the respiratory tract

Section 9.1, p. 287

7. inhalation—ribs move upward, diaphragm moves downward; exhalation—ribs move downward, diaphragm moves upward
8. Narrower airways decrease airflow during inhalation and exhalation.
9. less blood flow, less oxygen to the cells of the body

9.2 Practice, p. 288

1. (a) atmospheric air; cells
   (b) oxygen diffuses from an area of high partial pressure to an area of low partial pressure
2. cells; atmospheric air

Section 9.2, p. 291

1. A gas diffuses from an area of high pressure in the alveoli to an area of low pressure in the blood.
4. atmosphere, alveoli, blood plasma, red blood cells, hemoglobin
5. speeds the conversion of carbon dioxide and water to carbonic acid

9.3 Practice, p. 295

1. inflammation of the bronchial tubes; tissue swelling, excess mucus production, narrowing of the bronchial tubes, reduced air flow

Section 9.3, p. 297

1. stimulate chemoreceptors in the medulla oblongata
5. dissolves in plasma; combines with hemoglobin to form carbamino-hemoglobin; combines with water from the plasma to form carbonic acid
6. allows a greater number of foreign particles to enter the lungs
9. air in lungs allows more X rays to pass through; tumour blocks more X rays

Section 9.4, p. 304

1. the sheath that surrounds muscle fibres
2. actin and myosin

3. thin actin filaments and thick myosin filaments overlap and produce a striped appearance
4. to provide energy
5. It ensures ATP supplies remain high by supplying a phosphate to ADP.
6. tetanus, which is due to repeated muscle stimulation
7. sprinting—athlete A; long-distance running—athlete B

Chapter 9 Review, pp. 308–309

9. W—alveolus; X—trachea; Y—bronchiole
10. X
11. Y
13. (a) approximately 2.2 s
    (b) approximately 1.0 s
    (c) approximately 3.0 s
17. fetal hemoglobin—fetus secures oxygen from the mother's blood

10.1 Practice, p. 316

1. change in the diameter of the arteries following heart contraction
2. vasodilation—widening of blood vessel; vasoconstriction—narrowing of the blood vessel
3. diffusion of gases, nutrients, and wastes between the blood and surrounding cells

Section 10.1, p. 318

1. Blood rushes into capillaries.
2. no—if open all the time, blood rushing into capillaries would cause a dramatic drop in blood pressure
3. advantage—small distance for diffusion of gases and nutrients; disadvantage—easily damaged
5. may rupture, causing hemorrhage
7. Skeletal muscles massage blood back to the heart; veins have one-way valves to prevent back flow of blood.
8. pooling of blood in veins; avoiding standing for long periods
9. (b) restricted blood flow to organs; high blood pressure
   (c) medication to reduce cholesterol; balloon angioplasty

10.2 Practice, p. 320

1. systemic—carries oxygenated blood to the tissues of the body and deoxygenated blood back to the heart; pulmonary—carries deoxygenated blood to the lungs and oxygenated blood back to the heart
2. AV valves—prevent the back flow of blood from the ventricles into the atria; semilunar valves—prevent the back flow of blood from the arteries into the ventricles
3. chest pain; too little oxygen reaching the heart due to narrowing of the coronary arteries
4. operation to divert blood flow around a blockage to maintain adequate oxygen for heart muscle

10.2 Practice, p. 323

5. muscle that contracts without external nerve stimulation
6. sympathetic—prepares the body for stress; parasympathetic—returns the body to normal following adjustments to stress

10.2 Practice, p. 325

7. diastole—relaxation of the heart during which the cavities of the heart fill with blood; systole—contraction of the heart during which blood is pushed out of the heart
8. closing of the heart valves
9. faulty heart valves

Section 10.2, p. 327

1. atria—thin-walled chambers of the heart that receive blood from veins; ventricles—thick-walled chambers of the heart that deliver blood to the arteries
2. Blood flows one way through arteries and veins.
5. stronger in carotid artery because it is closer to the heart
8. beats faster, contracts with more force, increases in mass
9. a recording of the electrical impulses of the heart
13. advantage—do not carry antigens therefore rejection is less likely, do not harbour viruses and other infectious diseases; disadvantage—do not work as well as real hearts
14. beta 1 blocker

10.3 Practice, p. 332

1. high blood pressure
2. increase it
4. different body mass, less effective respiratory system

Section 10.3, p. 335

1. Increased stroke volume increases cardiac output.
4. no
5. heart is at the same level as the blood pressure receptors; less pressure needed to get blood to the head
7. Erect hair traps warm, still air to help reduce heat loss.
8. wearing clothes to stay warm, being in the sun
9. Core body temperature (rectal) is usually higher than oral temperature, which is affected by movement of cooler air into mouth.
12. A—sweating; B—evaporation; C—adjustment; D—shivering; E—adjustment
13. reduce fat in diet; increase physical activity

10.4 Practice, p. 337

1. arterioles
2. greater
3. filtration

Section 10.4, p. 339

1. fluid pressure and osmotic pressure
4. open-ended vessels that transport lymph fluid; they join the venous system
5. fluid that contains some small proteins; transported in lymph vessels; the venous system
6. They produce antibodies.
7. a reservoir for blood and a filtering site for lymph

Chapter 10 Review, pp. 346–347

9. 1 and 2
10. 5
11. 4 and 7
13. false
14. It pumps blood a greater distance.
15. high blood pressure; heart attack
21. Constriction of arterioles reduces blood flow to placenta.

11.1 Practice, p. 352

1. plasma, cellular components
2. albumin—maintain osmotic pressure in capillaries; globulins—antibodies; fibrinogens—blood clotting
3. carry oxygen
4. high altitude, hemorrhage
5. reduction of blood oxygen levels
6. initiate blood clotting

Section 11.1, p. 356

1. red blood cells—transport oxygen
3. undetermined—they have no nucleus when they are mature
4. anemia, hemorrhage
5. have nuclei when mature; don't carry hemoglobin
6. destroy invading microbes; form antibodies
7. form a plug to stop bleeding; release substances to trap more platelets and cause clotting proteins to form
8. embolus—dislodged blood clot; thrombus—blood clot that blocks a blood vessel
9. advantages—long storage time, no need to match blood type, no viruses; disadvantages—no clotting or immunity function
10. B

11. bacterial or viral infection
12. C
13. A
14. to increase the amount of oxygen delivered to tissue
15. Rh+ red blood cells have Rhesus antigen
16. it has no A or B antigens; it has both A and B antigens
17. B, O: agglutination of blood; A, AB: no agglutination
18. Antibodies from mother destroy red blood cells of fetus.

Section 11.2, p. 366

1. destroys the cell walls of foreign bacteria
4. swelling—sign of the inflammatory response; pus—phagocytosis is occurring
9. low—autoimmune disease is destroying leukocytes; high—infection

Section 11.3, p. 370

1. overreaction by the immune system
3. increases heart rate, compensating for the drop in blood pressure
4. Immune system attacks cells of the body as if they were foreign.
6. to reduce rejection of the donated organ by the recipient

Chapter 11 Review, pp. 374–375

11. memory B cells quickly stimulate the antibody-producing B cells
12. T lymphocytes—processed by the thymus gland, do not produce antibodies; B lymphocytes—produce antibodies
13. Protein coat allows it to attach to cell.
15. chemical messenger between T cells and B cells
16. (a) puncture membranes of cells infected with foreign invaders
    (b) read a blueprint of the invader and pass it on to B cells, which produce antibodies
    (c) turn off the immune system
    (d) retain information about the shape of an antigen
17. they had no immunity
18. cells capable of differentiating into a number of different specialized cells
21. X
22. Z
23. Y
24. antibiotics might be used as treatment
25. they indicate the presence of a microbe

12.1 Practice, p. 380

1. elimination of wastes and regulation of pH and water balance
2. removal of an amino group from an organic compound

Section 12.1, p. 386

1. Two kidneys provide a backup if one kidney fails.
2. filter blood
3. (a) D—kidney
   (b) E—ureter
   (c) C—renal artery
   (d) F—bladder
5. (a) glucose in the blood exceeds threshold level
   (b) excess glucose in nephron creates strong osmotic force, drawing water into nephron

Section 12.2, p. 392

1. precipitation of mineral solutes from the blood
7. rejection of the donor kidney by the recipient
8. (a) D
   (b) decreased blood pressure would decrease filtration and urine output
   (c) glucose in nephron creates an osmotic force, drawing fluids from the extracellular fluid into the nephron, increasing urine production

Chapter 12 Review, pp. 396–397

7. (b), (c), (e), (f), (a), (d)
8. proteins
9. urea
10. glucose
11. diffusion; dialysis solution
13. mitochondria provide ATP
15. increase
18. reduce filtration, thereby decreasing the amount of urine
20. it decreases

Unit 20 D Review, pp. 398–401

15. (a) capillary
    (b) aorta
16. (a) 10—diaphragm
    (b) 5—left bronchus
    (c) 2—epiglottis
    (d) 9—lung
17. (a) flask 2
19. emphysema, cardiovascular disease (heart attack and stroke)
20. 1—pancreatin and bile salts are needed for the digestion of fats and proteins
21. Fats are digested to fatty acids and proteins are broken down to amino acids, which both lower pH.
22. Bile salts in test tube 4 cause emulsification allowing pancreatin to chemically digest more of lipids.
23. Only physical digestion has occurred.
24. myoglobin
25. approximately 55 mmHg
26. approximately 40 mmHg
37. the state of constant muscle contraction caused by sustained nerve impulses

Unit 30 A

Section 13.1, p. 414

3. III, II, I

13.2 Practice, p. 418

2. A nerve of muscle responds completely or not at all.

Section 13.2, p. 425

1. They are very large.
3. opens at A
4. at peak between B and C

13.3 Practice, p. 429

1. cerebrum, corpus callosum, thalamus, hypothalamus, olfactory bulbs
2. cerebellum, pons, medulla oblongata
3. corpus callosum
4. acts as a relay station between cerebellum and medulla

Section 13.3, p. 432

3. right and left hemispheres could not communicate
5. cerebrum—contains the area of memory

Section 13.4, p. 435

2. preganglionic neurons, postganglionic neurons
3. innervate the heart bronchi, liver, pancreas, digestive tract

Chapter 13 Review, p. 441–443

15. cerebellum
17. 20 mV.
18. Neuron B

Section 14.1, p. 448

1. chemical—taste buds, olfactory cells; mechanical—skin; heat—skin; light—eye; sound—ear

14.2 Practice, p. 541

1. sclera, choroid layer, retina

Section 14.2, p. 455

2. adjustment of lens to near and far
3. rods respond to low-intensity light

Chapter 14 Review, pp. 466–467

11. 25 °C
12. 42 °C
20. effect of age on near-point accommodation
21. As age increases, near-point accommodation decreases.
22. 50 years

15.1 Practice, p. 472

1. Internal environment is maintained despite changes in external environment.

15.1 Practice, p. 475

4. chemical produced by an endocrine
5. no

Section 15.1, p. 477

3. have specific receptor sites which bind with hormones

15.2 Practice, p. 482

6. stimulates liver to convert amino acids into glucose

Chapter 15 Review, pp. 501–502

12. thirst, tiredness
21. Does caffeine affect endurance of athletes or non-athletes?
23. both decaffeinated treatments
25. caffeine effects endurance of athletes only

Unit 30 B

16.1 Practice, p. 514

1. unable to produce viable sperm

16.1 Practice, p. 515

3. formation of sperm

16.2 Practice, p. 522

1. contains oocyte

16.2 Practice, p. 526

4. FSH and LH regulate production of estrogen and progesterone

Section 16.2, p. 529

4. Menstrual cycle would not be initiated.
5. test to diagnose cervical cancer
6. (a) ovum would not reach the uterus
   (b) yes—hormones that trigger menstruation and ovulation are produced

16.3 Practice, p. 532

1. amnion—protects embryo; allentois—provides blood vessels to placenta

Section 16.3, p. 544

1. mass of undifferentiated cells which implants in the endometrium
2. prevents corpus luteum degeneration; avoids menstruation

Unit 30 B Review, pp. 548–551

15. sperm not viable
17. reduces availability of testosterone receptor sites causing testes to atrophy
18. decreases secretion of GnRH
22. X
23. Z
32. Identical twins result in 1 corpus lutei; fraternal twins result in 2.
34. in vitro fertilization
35. genetic mother has blocked Fallopian tubes and is unable to carry fetus

Unit 30 C

17.1 Practice, p. 562

1. interphase, prophase, metaphase, anaphase; telophase
2. 10

Section 17.1, p. 564

1. Genetic material must replicate.
2. pro—prior to; meta—occurring later than; ana—backward; telo—end
3. genetically identical; daughter cells smaller, fewer organelles
4. microtubules—direct chromosomes
5. produces two distinct cells; single cell with two nuclei
6. divide or die
7. dead cells not replaced; organism would die
8. Both sister chromatids moved to the same pole.
10. regulates the number of cell divisions
12. (a) 36 h—dividing at slower rate
    (b) 24 h cell
13. blood, skin, digestive tract
14. cells divide too quickly to specialize
15. no—blood cells continually replaced

17.2 Practice, p. 569

2. developed from the same fertilized egg
3. no
4. a cell with no nucleus

Section 17.2, p. 571

1. nucleus from one cell removed and inserted into cytoplasm of another
2. cloned from an adult cell
3. Females would be able to produce females by cloning.

17.3 Practice, p. 575

1. the formation of gametes
2. Haploid cells have half the number of chromosomes.
3. a pair of homologous chromosomes, each with two chromatids
4. chromosomes similar in shape, size, genetic arrangement, information
5. yes
6. no

Section 17.3, p. 581

1. first—homologous chromosomes separate; second—chromatids separate
2. new combinations of genetic material due to crossing over
4. (a) 22
   (b) 11
   (c) 22
8. (a) B and C
   (b) 6
9. (a) Z
   (b) W and X
10. male determines sex of the child
11. female; genetically identical to the mother

17.4 Practice, p. 586

1. Klinefelter syndrome

Section 17.4, p. 586

1. Both homologous chromosomes move to the same pole.
2. monosomy—1 homologous chromosome; trisomy—3 homologous chromosomes
3. trisomy of chromosome 21
4. pictorial representation of homologous chromosomes
5. monosomy (XO) of sex chromosomes

Chapter 17 Review, pp. 593–595

14. Skin becomes thicker if cells are damaged due to abrasion.
15. nondisjunction
21. female A
22. D—9; E—8; F—7
23. fertilization
24. zygote E
25. D—trisomy; F—monosomy

Section 18.1, p. 600

2. each allele located on a homologous chromosome
3. genotype—*RR*; phenotype—round seeds
4. (a) homozygous—*BB*; heterozygous—*Bb*
   (b) no—yellow dog must have two yellow alleles
5. (a) *Rr* and *rr*
   (b) *R* and *r*
   (c) both *r*
   (d) *Rr* and *rr*; 1/2 round, 1/2 wrinkled

18.2 Practice, p. 602

1. 100 % tall
2. 100 % red; 100 % *Rr*

18.2 Practice, p. 604

3. perform a test cross of red male and yellow female
4. both *Rr*

Section 18.2, p. 604

1. (b) *ss*; non-spotted
2. both *Hh*

18.3 Practice, p. 606

1. (a) 4
   (b) both *Dd*
   (c) both *dd*

Section 18.3, p. 607

1. (a) *Hh*
   (b) *hh*
   (c) 3
2. (a) 3
   (b) 5
   (c) 1—*Pp*; 2—*pp*
   (d) probability of inheriting *P* allele is 50 %
   (e) no

18.4 Practice, p. 609

1. 1:1 wild-type eyes:apricot eyes

Section 18.4, p. 612

1. (a) C^hC^a and C^aC^a; 50 % Himalayan, 50 % albino
   (b) full-colour—CC^a; light-grey—$C^{ch}C^a$
   (c) $C^{ch}C^{ch}$ and $C^{ch}C^a$; 50 % chinchilla, 50 % light grey

(d) $C^{ch}C^{h}$
2. 1:1 $C^{m}C^{m}$ to $C^{m}C^{r}$; 1:1 cremello to palomino
3. skin colour

18.5 Practice, p. 616

1. (a)
(b)
(c)

Section 18.5, p. 619

1. (a) *BbSs* and *Bbss*; 1/2 black short, 1/2 black long
(b) *BbSs, Bbss, bbSs, bbss*; 1/4 black short, 1/4 black long, 1/4/ white short, 1/4 white long
(c) BBSs, *BbSs, BBss, Bbss*; 1/2 black short, 1/2 black long
2. male—*BbHh*; female A—*bbHH*; female B—*BbHh*; female C—*bbhh*
3. A, Rh+; A, Rh–; O, Rh+; O, Rh–

Chapter 18 Review, pp. 623–625

10. male—*Tt*; first female and her foal—*tt*; second female—*tt*; second foal—*Tt*; third female—*Tt*; third foal—*tt*
11. (a) A or B
(b) AB—yes; O—no
13. codominance
14. 25 % $T^{m}T^{m}$, 50 % $T^{m}T^{n}$, 25 % $T^{n}T^{n}$
16. no
17. male—$H^{n}H^{n}$ (normal) with female—$H^{n}H^{B}$
18. no—females must be $H^{B}H^{B}$ to be bald

Section 19.1, p. 634

2. sex cells—haploid; somatic cells—diploid
4. hemophilia, colour blindness
6. (a) if mother heterozygous, hemophilic male offspring possible
(b) father—hemophilic; mother—carrier or hemophilic
7. (a) $X^{C}X^{c}$ and $X^{C}Y$; all have colour vision
(b) $X^{C}X^{C}$ $X^{C}X^{c}$ $X^{C}Y$ $X^{c}Y$; 75 % normal colour vision, 25 % colour blind (male)
(c) father—$X^{c}Y$; mother—$X^{C}X^{c}$ or $X^{c}X^{c}$

19.2 Practice, p. 639

1. B → 4 → A → 10 → C

Section 19.2, p. 641

1. closer genes less likely to crossover
2. increases variability
3. (a) A → 12 → C → 11 → B
(b) X → 6.25 → Y → 2.25 → Z

Chapter 19 Review, pp. 657–659

14. P_1—$X^{W}X^{w}$, $X^{W}Y$; F_1—$X^{W}X^{W}$, $X^{W}X^{w}$, $X^{W}Y$, $X^{w}Y$
16. Y-linked trait
17. 1—normal female; 2—normal male
18. 25 %
19. 50 %
20. 4: $X^{H}X^{h}$; 5: $X^{H}Y$
23. *C* and *S*
24. *FV* allele—between *C* and *B* alleles

20.1 Practice, p. 663

2. pairing does not allow for hydrogen bonding
3. 3'–TACGGAAT–5'

Section 20.1, p. 666

2. purine—double ringed; pyrimidine—single ring
4. thymine—20 %, adenine—20 %, guanine—30 %, cytosine—30 %
6. 2.2×10^{8}

20.2 Practice, p. 669

1. AUGAUGCCAUCCAUAU
2. (b) ATAATAT

20.2 Practice, p. 671

3. AUGCCUAAAGAGGCUU UAAUCCC
4. Met-Pro-Ser-Ile-Pro-Gly-Arg-stop
5. 15

Section 20.2, p. 676

1. DNA to mRNA to protein
2. ribosomes—synthesize protein; mRNA—template for protein synthesis; tRNA—delivers amino acids to ribosome
4. CCUAGUCCAGGUCCGU UAAAUCGUACGGGGUU
5. Met-Gly-His-Tyr-Phe-Ala-Arg-Cys-Gly-Gly-Ala-stop
6. 15
7. (a) RNA polymerase will continue to transcribe and build mRNA beyond the gene.
(b) Transcription will not take place.
10. D

20.3 Practice, p. 681

1. (a) 5'–AATTCGCCC GGG ATATTACGGATTATGC ATTATCCGCCC GGG ATATTTTAGCA–3'
3'–TTAAGCGGG CCC TATAATGCCTAATACG TAATAGGCGGG CCC TATAAAATCGA–5'
(b) 3
(c) blunt ends
2. sticky ends
4. GCGCTAAGGATAGCATTC GAATTCCCAATTAGGATC CTTTAAAGCTTATCC CGCGATTCCTATCGTAAG CTTAAGGGTTAATCCTAG GAAATTTCGAATAGG

Section 20.3, p. 686

2. (a) digest foreign DNA or DNA that is unmethylated
3. blunt ends—ends fully base-paired; sticky ends—possess single-stranded overhangs
4. recognition site—DNA sequence that a restriction endonuclease recognizes and cuts

Section 20.4, p. 694

2. can change the reading frame
3. nonsense
4. UV radiation, X rays, chemicals
5. (a) single-base substitution—no effect
(b) nonsense mutation—UAA is a stop codon, protein is not fully translated
(c) frameshift mutation—different amino acids
(d) frameshift mutation—different amino acids
(e) inversion—different protein is synthesized
6. (a), (c), (d)

Chapter 20 Review, pp. 702–704

11. TTAACGTAT
13. adenine—22.5 %; thymine—22.5 %; cytosine—27.5 %; guanine—27.5 %
16. lys–tyr–ser
20. CGTCATCGATCATGCAGC TC
24. valine
25. repeating valine amino acids—cause protein to have different function
29. mtDNA
31. PCR and gene sequencing

Unit 30 C Review, pp. 705–711

17. whitefish: I—81 %; P—10 %; M—5 %; A—1 %; T—3 %
frog: I—88% ; P—6 %; M—5 %; A—0 %; T—1 %
18. prophase
21. interphase
22. prophase
24. X—meiosis I; Y—meiosis II
26. C
27. 22
29. 47
30. yes—XX girl, XY boy
32. Z
33. Z
35. all black short hair
36. 9:3:3:1
37. A—*RRFf*; B—*RrFF*; C—*RrFf*; D—*RrFF*
38. 9 black : 3 brown : 4 albino
41. normal—Met-Gln-Val-Thr-Ser-Val; mutated—Met-Gln-Val-Thr-Tyr-Leu-Ser
42. normal—TACGTCCACT GGAGTCAC; mutated—TACGTCCACTGTATGGAG TCAC
43. TACGTCCACTGTATGGAG TCAC; insertion mutation

Unit 30 D

21.1 Practice, p. 720

1. *M*—0.85; *m*—0.15
2. *WW*—0.81; *Ww*—0.18; *ww*—0.01
3. (a) *T*—0.995; *t*—0.005
(b) *TT*—0.99; *Tt*—0.01; *tt*—0.000025 (embryos do not survive)
(c) *T*—0.995: *t*—0.005

(d) no significant effect

Section 21.1, p. 722

5. (a) no
   (b) yes
   (c) no
   (d) no
7. (a) *c*—0.02; *C*—0.98
   (b) 3.92 %
   (c) 0.0392 × Caucasian population number
8. (a) *h*—0.4; *H*—0.6
   (b) 36 %

Chapter 21 Review, pp. 734–735

17. no
18. *C*—0.98
19. *A*—0.095
22. *k*—0.32; *K*—0.68
23. 44 %

22.1 Practice, p. 739

1. 0.17 turtles/ha
3. If unliveable space is 40 ha, then ecological density is 0.21 turtles/ha.
4. 28 mosquitoes/ha; 28 000 mosquitoes/m^3

Section 22.1, p. 741

3. (a) 0.012 to 0.014 bears/ha
4. 275

22.2 Practice, p. 745

2. (a) up 7.2×10^7
   (b) up 2.0×10^5

22.2 Practice, p. 747

3. (a) 2 days
   (b) 22 days; 11 doubling times

Section 22.2, p. 750

1. *gr*—4 /year
2. 87
4. (a) exponential growth
5. (a) *gr*—-40 individuals/year; *cgr*—-0.20
6. (a) S-shaped curve
   (c) about 300

Section 22.3, pp. 756–757

2. (a) density dependent
   (b) density independent
   (c) density independent
5. (a) density dependent
6. (a) *K*-selected
   (b) *r*-selected
   (c) *r*-selected
   (d) *r*-selected
   (e) *K*-selected
   (f) *K*-selected

Chapter 22 Review, pp. 760–761

14. *N. insignis*, Plot 1—7.3/ha; *Z. hudsonius*, Plot 2—4.6/ha; *N. insignis*, Plot 3—5.8/ha; *Z. hudsonius*, Plot 3—1.3/ha
16. intraspecific competition
19. (b) about 300
21. greatest growth—1975–1985; est. population 2055—5 000 000; est. population—221 480 000

Section 23.1, p. 771

1. (a) exploitative competition
   (b) interference competition
   (c) interference competition
   (d) resource partitioning
3. (a) camouflage
   (b) active chemical defence (toxins)
5. mutualism
6. Both populations increase in the absence of competition.

Section 23.2, p. 775

4. forest fires; harvesting of the forest

Chapter 23 Review, pp. 780–782

5. (a) camouflage
(b) mimicry
(c) toxic sting
   (d) thorn

Unit 30 D Review, pp. 782–786

16. European: *l*—0.2; *L*—0.8; Aboriginal: *l*—0.92; *L*—0.08
18. (a) 28 125/m^2
    (b) 1.4×10^7 black flies
19. (a) 3.0/km^2
32. exponential
33. 250 000 to 300 000